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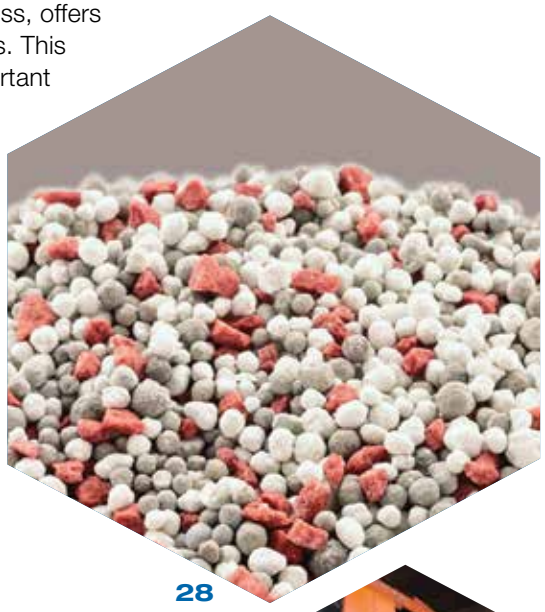
Cover Story



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Cover design: Rob Hudgins

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Editor's Page

Staying connected while apart

The new threat of the novel coronavirus is gripping the world and changing our lives quickly, drastically, and in ways we have never experienced in this generation. The news and scenes broadcast from countries around the world are stunning as we witness and experience schools and businesses closing, orders to shelter-in-place, and the empty streets of what are usually bustling cities.

Conferences and exhibitions

As directives to halt gatherings grow more stringent at the time of writing this column, tradeshows and conferences are being cancelled or postponed. In this issue, we included previews to three tradeshows that have been postponed. We decided to keep the previews in the issue so that readers can still have a look at some of the products and services that would have been on display, and are expected to be when the shows do take place. The three postponed events are: ***Interphex*** (www.interphex.com), originally planned for April 28–30, and will now be July 15–17 at the Javits Center in New York City; ***The International Powder & Bulk Solids Conference and Exhibition*** (powderandbulkshow.com), originally scheduled for April 28–30 is now scheduled for October 6–8 at the Donald E. Stephens Convention Center in Rosemont, Ill.; and ***IFAT*** (ifat.de) originally scheduled May 4–8, is now planned September 7–11 in Messe Munich, Germany

In addition, the American Institute of Chemical Engineers (AIChE; www.aiche.org) Spring Meeting has been postponed until August 16–20, and the American Chemistry Council's (ACC; www.americanchemistry.com) GlobalChem Conference and Exhibition has been cancelled.

Impacts on the CPI

The pandemic is affecting all industries, including the chemical process industries (CPI). The Occupational Safety and Health Administration (OSHA; www.osha.gov) has issued guidance on "Preparing Workplaces for COVID-19," which can be found on its website. The Society of Chemical Manufacturers and Affiliates (SOCMA; www.socma.org) reports that companies are reviewing pandemic plans and evaluating personnel issues, such as how to handle sick leave and telework policies. SOCMA is in touch with federal agencies about the impact of COVID-19 on the chemical supply chain and its website offers updates and various COVID-19-related resources. And the ACC issued a letter to the U.S. President and all state governors outlining the crucial role of the CPI in the manufacturing supply chain.

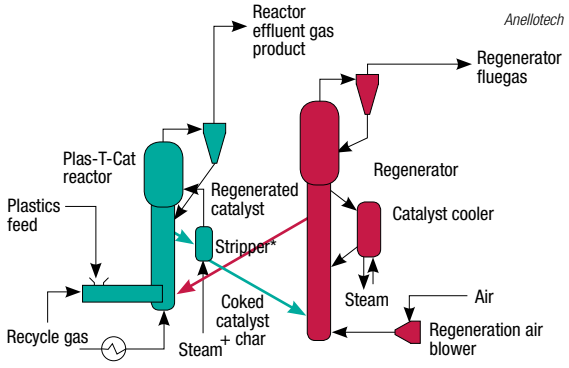
During this time when travel and face-to-face meetings are not recommended, we are turning to more online resources for information as well as a sense of community. At *Chemical Engineering*, we are continuing to update our website (www.chemengonline.com) with latest news and our many technical articles. As always, our current issue is freely available to all readers. We invite you to read our articles and start a conversation with the comments section at the bottom of each article, if you choose to do so. We also have numerous "live" webinars scheduled that are also free for all to join, thanks to our sponsors. You can check the "webinar" tab on the top of our homepage for upcoming topics and to register to join us.

COVID-19 is showing us just how vulnerable we are as humans. And yet it is our humanity that shines through at these times of crisis as we reach out and help each other, even as we keep our "social distance." Let's focus on the positive and stay connected, even while physically apart. ■

Dorothy Lozowski, Editorial Director

Conversion of plastic packaging to BTX and olefins is demonstrated

Anellotech (Pearl River, N.Y.; www.anellotech.com) recently announced a successful laboratory demonstration of a process to convert mixed plastic waste into a host of useful starting materials for new plastics. The process (diagram), known as Plas-T-Cat, would take place in a fluidized-bed reactor, and is envisioned to convert plastics, such as thin-film snack-bag packaging, into olefins (ethylene and propylene), BTX (benzene, toluene and xylenes) and other products.



With heat to effect polymer chain cracking, and ZSM-5 zeolite catalysts to control the reforming reactions from the pyrolysis gas, Anellotech's proprietary process has the potential to, within the same unit, convert polyolefins alone or as part of composite packaging. "The catalytic pyrolysis has the potential to generate commercially relevant yields of olefins, while reducing the mixture of waxes that you would see in a non-catalytic process," explains David Sudolsky, CEO of Anellotech. "Alternatively, we can adjust the operating conditions to obtain a higher proportion of BTX, along with lower-molecular-weight olefins, paraffins, C5 liquids and other compounds."

It is believed that the Anellotech process can deal with the unique set of contaminants observed in multi-layer packaging, such as color and an aluminum layer, says Sudolsky.

The plastic-waste process is related to the company's Bio-T-Cat process, which converts biomass to BTX, and has been operating at pilot scale since 2018 (*Chem. Eng.*, March 2016, p. 7).

Anellotech is nearing completion of engineering work for the first commercial-scale Bio-T-Cat plant, and will leverage the existing development infrastructure to pilot the new Plas-T-Cat process.

Progress towards lithium-sulfur batteries

An international team, led by Mahdokht Shaibani from Monash University (Melbourne, Australia; www.monash.edu), has developed an ultra-high capacity lithium-sulfur battery with better performance and lower environmental impact than current Li-ion batteries.

The team includes people from Monash University, University of Liège (Belgium), Fraunhofer Institute for Material and Beam Technology (Dresden, Germany), Technische Universität Dresden (Germany), and CSIRO (Melbourne, Australia; www.csiro.au).

Using sulfur cathodes in Li-S batteries and silicon anodes in Li-ion batteries is the most attractive example of inexpensive electrodes with excellent ability to store lithium, and hence the potential to outperform today's Li-ion batteries. However, a problem with these electrodes is the structural fragmentation associated with the volume change during the absorption and release of large quantities of lithium. These changes lead to a loss of cohesion of particles and permanent distortion of the polymer binder and carbon matrix, both of which contribute to loss of capacity.

According to the team, little attention has been devoted to the mechanical failure of thick cathodes in cycling duty. Binders, essential in the electrode composition to glue the active material and conductive agent together and also to the current collector, must be able to make crack-free cathodes. Thick cathodes, if started at high capacities, showed rapid degradation due to the mechanical failure or did not deliver high capacities.

The team reported that controlling the dispersion of Na-carboxymethylcellulose (a commonly used binder) enables the formation of mechanically strong bridging bonds between the fillers — in the case of the team's work, colloidal sulfur and conductive carbon. The team fabricated four types of thick sulfur cathodes with identical compositions (70% colloidal S, 20% C, and 10% carboxymethylcellulose) yet using different slurry preparation methods. Scanning electron microscopy was used to investigate the effect of slurry preparation on the morphology of these cathodes. The method the team used efficiently converted the compact microstructure into a unique architecture with an increase in free space to potentially accommodate the cycling stresses, and deliver a higher level of stability than that seen in any battery to date.

Edited by:
Gerald Ondrey

Li_2CO_3 FROM BRINE

Purities of greater than 99.9% for battery-quality lithium carbonate have been achieved using a proprietary artificial-intelligence-powered crystallization technology developed by Standard Lithium Ltd. (Vancouver, B.C.; www.standardlithium.com). The total cation contaminant levels were reduced from nearly 2,500 parts per million (ppm) to less than 139 ppm in the crystallization. Optimization work for the crystallization process, known as SiFT, was conducted at the University of British Columbia, and supports separate work related to the ongoing commissioning of Standard Lithium's LiSTR Direct Lithium Extraction demonstration plant in the Smackover brine region in south Arkansas (*Chem. Eng.*, July 2018, p. 9). The first-of-its-kind demonstration plant will use the Standard Lithium's proprietary technology to selectively extract lithium from tailbrine that comes from a nearby Lanxess facility.

'GREENER' ASPHALT

Last month, representatives from 22 organizations met at the Tech Park in Delft, the Netherlands for the official start of the bio-based-asphalt cooperation program, called CHAPLIN (Collaboration in aspHalt APplications with LIgniN). The cooperation aims to stimulate the development and commercialization of lignin-containing asphalt, as an alternative to bitumen from petroleum.

"There is a lot of interest worldwide for lignin as a sustainable raw material for bio-asphalt," says lig-

(Continues on p. 8)

nin expert Richard Gosselink of Wageningen Food & Biobased Research (WUR; the Netherlands; www.wur.nl), a partner in the CHAPLIN program and the project manager for CHAPLIN TKI, the first project that is already underway. "Lignin is released in enormous flows in processes of paper production," explains Gosselink, and "It remains as a residual stream that can be used much better than as 'burner fuel.' By adding lignin, we can currently green the asphalt for 50% and produce and apply it around 30°C less hot. That already saves around 20% CO_2 and half of fossil fuels," says Gosselink. "Moreover, lignin is interesting because, like bitumen, it gives structure and strength to asphalt and fixes CO_2 for a longer period of time. "

ENERGY STORAGE

Last month, Azelio (Gothenburg, Sweden; www.azelio.com) completed the installation of its renewable-energy storage system at Noor Ouarzazate solar complex in Morocco. An inauguration ceremony was held on March 5, 2020, together with the Moroccan Agency for Sustainable Energy (Masen; Rabat; www.masen.ma) and invited prominent guests.

The installation is a partial result of a joint technical and business development agreement between Azelio and Masen. A verification of the storage will be initiated during the first quarter of 2020, with commercial installations later the same year, followed by volume production in 2021.

Azelio's energy-storage system uses a phase-change material (PCM) heated (by the concentrated solar thermal energy) to just below 600°C and liquefied in a con-

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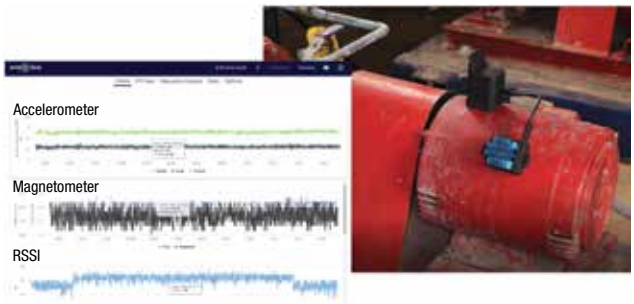
Batteryless machine-health monitor enabled by low-power computer chips

Everactive



Everactive (Charlottesville, Va.; www.everactive.com) has just launched its Machine Health Monitor (MHM) product for batteryless vibration and temperature sensing of process machinery (photo). The MHM harvests waste energy from small temperature differentials (10°F or greater) and ambient light (100 lux or greater) to power the sensor and to transmit wireless data continuously. The product joins Everactive's initial product, a batteryless industrial internet of things (IIoT) temperature sensor for steam-trap applications.

The batteryless sensor systems are made possible by ultra-low-power computer chips designed with sub-threshold circuits that operate continuously with miniscule levels of electricity. "There's nothing exotic about the chip materials and manufacturing process," explains Brian Alessi, marketing director for Everactive. "The ability to sense and transmit data continuously results from the careful design of the system as a whole, with the objective of operating under the 'energy ceiling' for harvested power."

Asset sensor systems represent a critical aspect of the trend toward digitalization and IIoT-enabled process optimization, but the sensors require power to detect signals and transmit data. Managing and replacing batteries for the number of sensors currently projected for industrial processes presents a large maintenance challenge. "If, as some analyses predict, one trillion sensors were installed on industrial assets, it would require replacing 913 million batteries daily," says Alessi. "And that is not sustainable, from a maintenance resource or environmental standpoint."

Thus far, Everactive has installed batteryless steam-trap sensors at about a dozen sites, and is rolling out the MHM product this month. The devices are built to be robust, Alessi says, with IP66 protection for dust and water, and compliance with Class 1, Div. 2 hazardous area requirements.

Oxidative precipitation recovers nickel and cobalt from ore

An alternative method for processing mixed nickel-cobalt hydroxide precipitate to separate the nickel from cobalt and manganese has been proposed by a team from the Bandung Institute of Technology (Bandung, Indonesia; www.itb.ac.id), the Indonesian Institute of Sciences (Bandung) and the University of Queensland (Brisbane, Australia).

Most existing process plants for nickel laterite ores use intermediate precipitation processes to recover the nickel and cobalt from the leach solution. The precipitation produces an intermediate product of nickel and cobalt, either as mixed sulfide precipitate (MSP) or mixed hydroxide precipitate (MHP), while largely separating nickel and cobalt from impurities such as manganese, calcium and magnesium.

Mixed sulfite precipitation processes have a higher selectivity for nickel and cobalt over manganese and magnesium, resulting in a lower level of impurities compared with mixed hydroxide precipitation. However, the operation of sulfide precipitation processes is relatively expensive and complex because they require use of hazardous hydrogen sulfide gas at high temperatures and pressures.

The hydroxide precipitation process is, therefore, favorable over sulfide precipitation, especially for simpler processing plants, because it avoids the complexity and capital investment required to recover the nickel and cobalt.

The new proposed method comprises a leaching step using sulfuric acid to dissolve the nickel and cobalt from mixed hydroxide precipitates, and subsequently, an oxidative precipitation step to separate the dissolved nickel from cobalt and manganese using ozone as the oxidant.

Leaching experiments showed that 97% of the nickel and 96% of the cobalt can be dissolved, while leaving 92% of the manganese in the residue using 1 mol/L sulfuric acid solution at 25°C, a slurry density of 100 g/L and leaching duration of 2.5 h. The results of the oxidative precipitation experiments showed that complete precipitation of the dissolved cobalt and manganese can be achieved by using ozone as oxidant with nickel co-precipitation of about 8.8% at 25°C, equilibrium pH of 5.0, oxidant gas flowrate of 1 L/min and precipitation duration of 2 h.

tainer. During discharge, the heat from the PCM is transferred, via heat-transfer fluid, to a sterling engine that drives a generator. The PCM is based on recycled aluminum, contains no rare minerals, and suffers no reduced capacity over time, says the company. The system is scalable from 100 kW to 100 MW, says the company.

TRI-METAL CATALYST

Last month, BASF SE (Ludwigshafen, Germany; www.basf.com) announced that it had successfully developed and tested its Tri-Metal Catalyst technology, which enables partial substitution of high-priced palladium with lower-priced platinum in light-duty gasoline vehicles without compromising emissions standards, according to BASF. Adoption of the Tri-Metal Catalyst can reduce catalytic-converter costs for automakers and partially rebalance market demand for platinum group metals (PGMs), thereby enhancing PGM market sustainability, the company adds.

The technology was developed in collaboration with, and support from, Sibanye-Stillwater (www.sibanyestillwater.com) and Impala Platinum Ltd. (both Johannesburg, South Africa; www.implats.za).

SINGLE ATOM CATS

Single atom catalysts (SACs) have attracted significant attention because they exhibit unique catalytic performance due to their ideal structure. However, maintaining atomically dispersed metal under high temperature, while achieving high catalytic activity remains a formidable challenge. Now, the research group of professor Hideo Hosono at the Tokyo Institute of Technology (TiTech; Japan; www.titech.ac.jp) has de-

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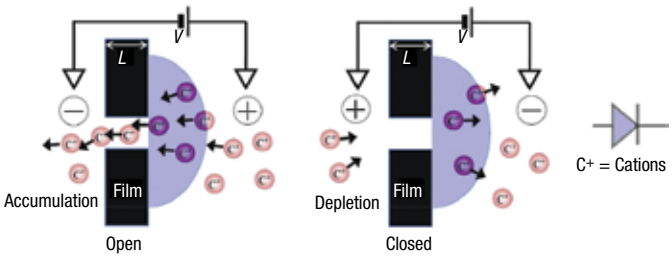
A desalination process that pumps ions instead of water



Researchers from Indonesia's Bogor Agricultural University (Bogor, Indonesia; www.ipb.ac.id), the University of Bath (U.K.; www.bath.ac.uk), and the University of Johannesburg (Johannesburg, South Africa; www.uj.ac.za), led by Budi Riza Putra, have developed a low-cost, low-energy and low-maintenance, solar-powered desalination system that can be operated in mobile units. The system could service a small number of households, or homesteads in remote locations where freshwater is scarce.

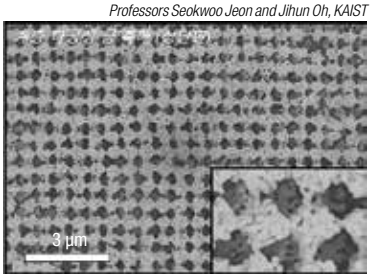
The prototype desalination unit is a 3D-printed system with two internal chambers designed to extract or accumulate salt (diagram). When power is applied, salt cations (positively charged ions) and salt anions (negatively charged ions) flow between chambers through arrays of micro-holes in a thin, negatively charged, membrane. The system combines the membrane with an anionic resistor that only allows the flow of negative ions when power is applied. As a result of this one-way flow, salt is pumped out of seawater. This contrasts with the classical desalination process, where water rather than salt is pumped though a membrane.

The proof-of-concept prototype is currently able to remove 50% of the salt from saltwater, but to make seawater drinkable, the salt content needs to be reduced by 90%. Another benefit of the unit is that it also allows for the opposite process — the up-concentration of salt — minimizing waste. The separated salt can be crystallized and then used either as a food supplement or as a de-icer. Most other desalination processes pump salt back into the sea, which could upset the marine ecosystem.

"We need to find new and better porous materials capable of pumping ions. Membrane thickness, pore number and pore diameter must all be optimized," says Putra. "We hope to find materials experts who can help us with this."

This gold catalyst improves CO_2 reduction

Professors Seokwoo Jeon and Jihun Oh, KAIST



Researchers from the Korea Advanced Institute of Science and Technology (KAIST; Daejeon; www.kaist.ac.kr) have developed a three-dimensional (3D) hierarchically porous nanostructured catalyst that is said to have a CO_2-to-CO conversion rate up to 3.96 times higher than that of conventional nanoporous gold catalysts. Described in the March 4 issue of the *Proceedings of the National Academy of Sciences*, this new catalyst is expected to help overcome the existing mass-transport limitations that have hampered existing electrocatalysts.

Gold is one of the most commonly used catalysts in CO_2 reduction reactions, but the high cost and scarcity of Au pose obstacles for mass commercial applications. The development of nanostructures has been extensively studied as a potential approach to improving the selectivity for target products and maximizing the number of active stable sites, thus enhancing the energy efficiency. However, the nanopores of previously reported complex nanostructures were easily blocked by gaseous CO bubbles during aqueous reactions. The CO bubbles hindered mass transport of the reactants through the electrolyte, resulting in low CO_2 conversion rates.

The KAIST research group, led by professors Seokwoo Jeon and Jihun Oh from the Dept. of Materials Science and Engineering, designed a 3D hierarchically porous Au nanostructure with two different sizes of macropores and nanopores (see scanning electron microscope image). The team used proximity-field nanopatterning (PnP) and electroplating techniques that are effective for fabricating the 3D well-ordered nanostructures.

The proposed nanostructure, composed of interconnected macroporous channels 200 to 300 nm wide and 10 nm nanopores, induces efficient mass transport through the interconnected macroporous channels as well as high selectivity by producing highly active stable sites from numerous nanopores. As a result, its electrodes show a high CO selectivity of 85.8% at a low overpotential of 0.264 V and efficient mass activity that is up to 3.96 times higher than that of de-alloyed nanoporous Au electrodes, according to KAIST.

Semiconducting material combines handedness and polarity

A material synthesized by researchers at Rensselaer Polytechnic Institute (RPI; Troy, N.Y.; www.rpi.edu) could enable new ways of manipulating electronic materials remotely using light. The material, explains RPI professor of materials science and engineering Jian Shi, derives its unique capabilities from the co-existence of both macroscopic electrical-field-switchable polarity and chirality. This combination of material properties in semiconductors has not been previously demonstrated. The new material's pyroelectricity (spontaneous electric polarization that can be reversed through the application of an electric field) combined with chirality (a spatial property of molecules or crystals that are non-superimposable with their mirror images) yields unprecedented material tunability when exposed to light sources of different polarization. This means that the material can be remotely manipulated to produce specific electric and magnetic properties, which could be especially advantageous in semiconductor applications.

The organic-inorganic hybrid crystal is made of carbon, iodine and lead and is synthesized via a wet-chemistry method with special precursors designed to enable both polarity and chirality. "Currently, the materials are synthesized in a laboratory beaker, but it would be easily scaled up," explains Shi, noting that scaleup would involve delicate control of parameters like nucleation and growth rate. The most promising electronics applications for this material, says Shi, include sensing, logic switching and memory.

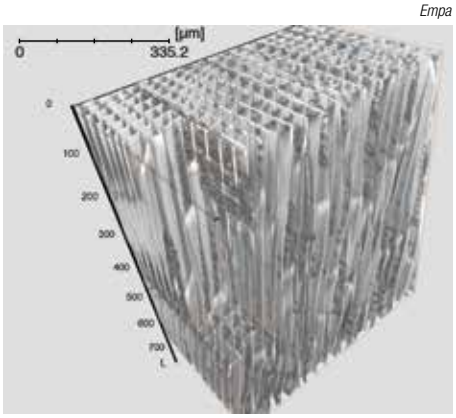
Wood-supported catalyst safely keeps fruit fresh

Ethylene is a multifunctional phytohormone that regulates growth, ripening and other functions in plants. For example, bananas stored next to apples will ripen quickly due to the ethylene released from the apples, which in turn are triggered to release more ethylene. This can cause a loss of food in the entire supply chain, from importer to the wholesale and retailer.

To counteract the accelerated ripening process, ethylene must be kept away from fruits and vegetables. For this purpose, researchers from the Swiss Federal Laboratories for Materials Science and Technology (Empa; Dübendorf; www.empa.ch) and ETH Zurich (www.ethz.ch) are developing a new catalyst that degrades ethylene, released by fruits and vegetables, into water and CO_2. The concept is based on a catalyst support made of delignified wood, which is then enriched with a platinum catalyst that is dispersed at an atomic level.

Wood consists of three basic substances: cellulose, hemicellulose and lignin. The researchers used a protocol developed in the Wood Materials Science professorship at ETH Zurich and Empa, and dissolved with the help of an acid solution both lignin, wood's binding substance, and a part of the hemicelluloses. This makes the remaining cellulose structure extremely porous with a very large

Empa



specific surface area (photo) — properties that make the delignified wood a perfect natural scaffold for a catalyst. The delignified wood is then put into two different solutions: The first creates a cerium-doped TiO_2 foundation that serves as the support for the platinum particles on the cell walls of the wood; the second contains the platinum particles, which then enter the wood structure.

The Empa team demonstrated that the catalyst decomposes virtually all of the emitted ethylene at room temperature. If the temperature drops to 0°C, however, water — one of the reaction products — can no longer evaporate, sticking to the catalyst and preventing any further chemical reaction. To rid the catalyst from the condensed water layer and make it work again, it is sufficient to warm up the entire structure for a few minutes every two hours, Lukovic says.

The concept of catalytically degrading ethylene to extend the shelf life of fruit is not new, since Hitachi (Tokyo, Japan; www.hitacji.com) has been producing refrigerators equipped with platinum catalysts since 2015. However, the Empa researchers have improved this concept by using a wood-based support instead of silica, and a more efficient utilization of the (rather expensive) platinum catalyst. The study was reported in a recent issue of the journal *ACS Nano.* ■

veloped a new, stable SAC for performing chemoselective hydrogenation of nitroarenes. The researchers were able to stabilize single platinum atoms within sub-nanometer surface cavities in well-defined $12CaO{\cdot}7Al_2O_3$ crystals (designated C12A7), using a combination of both theoretical prediction and experimentation. This approach utilizes the interaction of isolated metal anions with the positively charged surface cavities of C12A7, which allows for severe reduction conditions at temperatures up to 600°C. The resulting catalyst, 0.1Pt/C12A7, is said to be stable and highly active toward the selective hydrogenation of nitroarenes to anilines, with a much higher turnover frequency (up to 25,772 h^{-1}) than well-studied Pt-based catalysts.

AMMONIA

Tsuyoshi Nagaoka and colleagues at Nagoya University (Japan; www.nagoya-u.ac.jp) have demonstrated that the ammonia synthesis activity per weight of catalyst of Ru/Ba/LaCeOx, pre-reduced at 700°C, has the highest reported oxide-supported Ru catalysts, 52.3 mmol h^{-1} $gcat^{-1}$ at 350°C, 1.0 MPa. The turnover frequency of Ru/Ba/LaCeOx at 350°C was more than 8 times that of Cs^+/Ru/MgO, which is a well-known active catalyst used as a benchmark. Furthermore, hydrogen poisoning — a typical drawback for oxide-supported Ru catalysts — was effectively suppressed.

CO_2 UTILIZATION

VTT (Espoo, Finland; www.vtt.fi) and partners have started a two-year project to develop a process to capture and utilize CO_2. For the BECCU project, researchers are focusing on polyols as the primary end product. ❑

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Plant Watch

DOMO Chemicals to invest €12 million in new nylon plant in China

March 13, 2020 — DOMO Chemicals GmbH (Leuna, Germany; www.domochemicals.com) will invest €12 million for a new nylon production plant in Zhejiang, China. The new plant will be capable of producing 50,000 metric tons per year (m.t./yr) of engineered nylon compounds. Production is expected to commence in the fourth quarter of 2020.

Preem selects Topsoe technology for renewable-fuels plant

March 12, 2020 — Preem (Stockholm, Sweden; www.preem.se) has contracted Haldor Topsoe A/S (Lyngby, Denmark; www.topsoe.com) to provide process technology to produce renewable diesel and jet fuel at its Gothenburg refinery in Sweden. The 16,000 barrels-per-day (bbl/d) unit will have a yearly production capacity of approximately 1 million m^3 of fuels. The new plant is scheduled to start up in 2024 and will be completely dedicated to producing renewable fuels from tall oil, tallow and other renewable feedstocks.

Ontario plant to expand production of malic acid

Bartek Ingredients Inc. (Stoney Creek, Ont., Canada; www.bartek.ca) announced a 10,000-m.t./yr malic acid capacity expansion, to be completed in 2021. This expansion closely follows a 4,000-m.t./yr malic acid expansion completed in 2019, as well as the installation of a new 22,500-m.t./yr maleic anhydride reactor, which will also be operational in early 2021. With these expansions, Bartek will have in excess of 30,000 m.t. of malic acid capacity.

Axens to provide technology for new bioethanol plant in Croatia

March 9, 2020 — Axens (Rueil Malmaison, France; www.axens.net) was awarded a license agreement from Croatian oil-and-gas company INA to supply cellulosic ethanol technology for a new bioethanol production plant in Sisak, Croatia. INA plans to produce 55,000 m.t./yr of advanced ethanol based on lignocellulosic feedstock, such as agricultural residues and miscanthus.

Nouryon and Ineos Nitriles break ground on new facilities in Germany

March 4, 2020 — Nouryon (Amsterdam, the Netherlands; www.nouryon.com) and Ineos Nitriles have broken ground on new facilities to be built at Ineos' Cologne site in Germany. The units will produce raw materials for Nouryon's biodegradable chelate products, which are used in detergents and other products. The plants are due to be completed in 2021 and 2022.

Toray subsidiary breaks ground for new plant producing fuel-cell components

March 3, 2020 — Greenerity GmbH, the German subsidiary of Toray Industries Inc. (Tokyo, Japan; www.toray.com), held a groundbreaking ceremony in Alzenau, Germany for its second plant to produce catalyst-coated membranes and membrane-electrode assemblies, which are key components of hydrogen fuel cells. When the new plant goes online in November 2021, Greenerity's combined annual output from both plants will be around 10 million units.

Thailand plant to expand capacity for bio-based epichlorohydrin

March 2, 2020 — Bio-based chemical company Advanced Biochemical (Thailand) Co. (ABT), a wholly-owned subsidiary of the Vinythai public company (Bangkok, Thailand; www.vinythai.co.th), a group company of AGC, Inc., has announced a capacity increase at its plant in Map Ta Phut, Thailand, which will now produce 120,000 m.t./yr of bio-based epichlorohydrin, representing an increase of 20,000 m.t./yr.

DSM to expand Indiana compounding plant

Feb. 26, 2020 — Royal DSM N.V. (Heerlen, the Netherlands; www.dsm.com) is expanding the capacity of its high-performance materials compounding plant in Evansville, Indiana. With the investment, DSM will enhance the site to produce advanced materials, including polyamides and bio-based thermoplastics used for electrification, metal replacement and lightweighting in multiple industries. The project is expected to be completed in the third quarter of 2021.

Vinnolit commissions expanded paste PVC plant in Germany

Feb. 24, 2020 — Vinnolit GmbH & Co. KG (Ismaning, Germany; www.vinnolit.com) has commissioned its plant expansion for the production of paste polyvinyl chloride (PVC) at its Burghausen, Germany site. The site employs the company's microsuspension technology, and includes a new dryer, extended reactor capabilities, a new bagging plant and palletizing system, as well as several new siloes, to facilitate the increased production volume.

Mergers & Acquisitions

Yara to sell billion-dollar stake in QAFCO joint venture

March 10, 2020 — Yara International ASA (Oslo, Norway; www.yara.com) signed a share purchase agreement with Qatar Petroleum to sell its 25% share in joint venture (JV) Qatar Fertiliser Co. (QAFCO) for $1 billion. Since the establishment of QAFCO, the JV has become the world's largest single-site urea producer.

Saint-Gobain divests glass-processing assets in Germany
March 10, 2020 — Saint-Gobain S.A. (Courbevoie, France; www.saint-gobain.com) sold part of its glass-processing business, Glassolutions Germany, to DIK Deutsche Industriekapital GmbH. The divestment concerns seven German sites: Bremen, Flensburg, Freiburg, Kiel, Murr, Potsdam and Rostock. These sites delivered sales of €45 million in 2019.

Henkel and Covestro collaborate on adhesives for LIB assembly
March 3, 2020 — Henkel AG & Co. KGaA (Düsseldorf, Germany; www.henkel.com) and Covestro AG (Leverkusen, Germany; www.covestro.com) recently developed a solution enabling the efficient fixation of cylindrical lithium-ion battery (LIB) cells inside a plastic cell holder. The solution is based on an ultraviolet (UV) light curing adhesive from Henkel and a UV-transparent polycarbonate blend from Covestro.

Sekisui and Sumitomo join forces for waste-to-polyolefins conversion
Feb. 27, 2020 — Sekisui Chemical Co. (Osaka, Japan; www.sekisuichemical.com) and Sumitomo Chemical Corp. (Tokyo, Japan; www.sumitomo-chem.co.jp) will form a strategic alliance to deploy technology for manufacturing polyolefins using chemically recycled waste as a raw material. Pilot production will begin in 2022, with Sekisui Chemical turning waste into ethanol, and Sumitomo Chemical using this ethanol as a raw material for polyolefins. A full-scale launch of this process is expected in 2025.

Mitsubishi Chemical to boost plastics recycling with acquisitions
Feb. 26, 2020 — Mitsubishi Chemical Corp. (MCC; Tokyo; www.m-chemical.co.jp) will acquire two engineering plastics recyclers, Minger Kunststofftechnik AG and Minger Plastic AG (collectively, the Minger Group, headquartered in Appenzell, Switzerland; www.minger.ch). The Minger Group has proprietary recycling technologies for engineering plastics, such as polyether ether ether ketone (PEEK), polyvinylidene difluoride (PVDF) and nylon.

Avantium sells its bioaromatics portfolio
Feb. 26, 2020 — Avantium (Amsterdam, the Netherlands; www.avantium.com) has sold its bioaromatics patent portfolio to The Netherlands Organization for Applied Scientific Research (TNO). The sale includes patents and know-how for technologies that produce bio-derived products for polymers and coatings.

OCI and Posco form JV for hydrogen peroxide production
Feb. 24, 2020 — OCI Co. Ltd. (Seoul, South Korea; www.oci.co.kr) and Posco Chemical (Pohang-si, South, Korea; www.posco.com) signed a joint agreement to produce electronic-grade and industrial hydrogen peroxide using coke-oven gas (COG), a byproduct of steelmaking processes. The JV is scheduled to go into operation in the second quarter of 2020, with 49% of its shares owned by OCI and 51% by Posco Chemical, respectively. The two companies plan to build a hydrogen peroxide plant at OCI's Gwangyang site with a total production capacity of 50,000 m.t./yr. They are anticipating commercial production to begin in 2022.

Mary Page Bailey

A Push for 'Green' Crackers

Today's steam crackers are bigger than ever — those of tomorrow might be carbon neutral

Steam cracking is a key process of the petrochemical industry, whereby naphtha or other petroleum-based feedstock is thermally broken down (cracked) into smaller building-block compounds, such as ethylene, propylene, butadienes and BTX (benzene, toluene and xylenes), which are then processed into plastics, rubber and other polymers and chemicals. The feedstock is cracked within milliseconds as it flows through the furnace tubes at temperatures of around 850°C. Crackers are large, complex units with multiple furnaces — sometimes as many as ten — that are integrated with many different process units for separating and purifying the different olefins, which in turn are processed into products. Hence, crackers are at the heart of the aptly named petrochemical complex (Figure 1).

Although crackers will operate with the most economical feedstock, depending on the location, all crackers have one thing in common: today's cracker furnaces use fossil fuels to heat the tubes to the high temperatures required. As a result, the steam cracker is a major source of CO_2 emissions resulting from the combustion of fuels. In order to achieve the goals agreed upon in the Paris Agreement, Europeans are working to reduce the carbon footprint of their crackers. In the short term, that means improving the efficiency of the furnaces. For the future, efforts are underway to develop new, alternative ways for making olefins, including the use of electricity derived from solar or wind power generation.

Steam-cracker trends

"One main trend has been the increase in the size of plants worldwide," says Jim Middleton, manager of Technology and Ethylene Product Line Leader, TechnipFMC plc (London, U.K.; www.technipfmc.com). "Clients have been aiming to maximize the size of plant that can be designed as a single train, to maximize economies of scale." Plants producing 1.5–1.8 million tons/yr of ethylene from liquid and mixed-feed crackers, and 1.5–2.0 million ton/yr of ethylene from ethane gas crackers are becoming the norm for producers who are not feed- or product-constrained, he says.

TechnipFMC

FIGURE 1. Steam crackers are part of large petrochemical complexes, such as Chevron Phillips Chemical Co.'s Cedar Bayou plant in Baytown Texas. CPChem's 1.5-million m.t./yr ethane cracker started up in 2018

"In North America, the focus has been on producing ethylene from ethane derived from shale gas, and on capital efficiency. Elsewhere in the world, the focus has been mainly on naphtha, and particularly on an increasing proportion of LPG [liquefied petroleum gas] feeds," continues Middleton. "In both Asia and Europe, some world-scale cracker projects are being designed based on imported ethane feedstock," adds Dennis Mayfield, vice president Process Technology, TechnipFMC. "In the Middle East, the trend reflects the shortage of ethane availability, directing the investment into liquid feed or mixed ethane and liquid feed steam crackers. Ethane crackers in this region are expected when LNG [liquefied natural gas] producers expand their production facilities," contributes Yvon Simon, head of Technologies Department, TechnipFMC.

"[Petroleum] refinery operators outside the U.S. have been looking to move into the production of olefins to maintain capacity in response to the anticipated slow growth in the demand for fuels," says Middleton. "There is a trend to develop integrated refineries and steam cracker complexes or petrochemical refineries. The ultimate development of such a trend is the crude-to-chemicals concept. Oil-to-chemicals projects have been discussed, but few of these projects have moved to the implementation stage," says Simon.

"In Europe, the focus is on sustainability, particularly CO_2 reduction and capture, energy efficiency and recycling of plastics," says Middleton.

Steam-cracker improvements

"TechnipFMC has developed and implemented two particular new patented developments in furnace radiant coils — a Three Lane coil design and a Swirl Flow Tube design. Both of these offer improved run lengths and/or capacity for cracking furnaces. Both of these developments are in commercial operation," says Middleton.

"Radiant coil designs have evolved over the past few decades to meet greater industry demands," explains Mayfield. "This journey has been characterized by numerous small steps, as well as several vital, groundbreaking innovations. The triple-lane concept is the latest development in this lineage. It has several merits over preceding and competing developments, including: it reduces peak tube-metal temperatures; it is a simple and elegant way to improve run length, capacity and selectivity; it can be applied in revamps and new furnaces; and it is suitable for all cracker feeds, from ethane to VGO [vacuum gas oil]," says Mayfield.

TechnipFMC

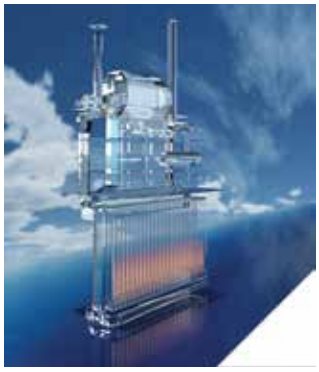


FIGURE 2. TechnipFMC has developed a new patented furnace design that exceeds the emissions reductions targets of the European Improof Project

"TechnipFMC sees improving the sustainability of cracking technology to be a key area of improvement in the next few years. In the medium term, moving to the use of more sustainable energy sources and reduction in fuel firing (and therefore CO_2 emissions) is seen as the path the industry will follow," says Middleton. "In addition, for some locations, the capture and storage of CO_2 will also be an option. In the longer term, methods of producing olefins without firing fuel (such as electric heating) may become viable, but it is important that these do not move the generation of CO_2 from the cracker to outside energy sources," he says.

TechnipFMC has been a key participant in the Improof project — a four-year European project aimed at improving the energy efficiency of steam cracking furnaces by at least 20%, while reducing emissions of greenhouse gases and NOx by at least 25%. "A new patented furnace design has been developed by TechnipFMC which exceeds these objectives," says Middleton. The project, with seven industrial partners, including Technip, Dow and John Zink Company LLC, and two universities, runs through August 2020.

Electrifying possibilities

As the availability and reliability of renewable electricity increases, and its costs fall, the chemical process industries (CPI) are looking for ways to electrify production, when possible, to not only reduce operating costs, but to reduce their environmental footprint. Because steam crackers are a major source of CO_2 emissions, petrochemical companies are now looking for ways to electrify.

In Europe, one such effort began last August with the formation of the "Cracker of the Future" Consortium. Six petrochemical companies in Flanders, Belgium, North Rhine-Westphalia, Germany, and the Netherlands (Trilateral Region) created the consortium to jointly investigate how naphtha or gas steam crackers could be operated using renewable electricity instead of fossil fuels. The Cracker of the Future consortium, which includes BASF, Borealis, BP, LyondellBasell, SABIC and Total, and is chaired by Brightlands Chemelot Campus (Sittard-Geleen, the Netherlands; www.brightlands.com), aims to produce base chemicals while also significantly reducing carbon emissions. The companies have agreed to invest in R&D and knowledge sharing as they assess the possibility of transitioning their base chemical production to renewable electricity.

Following the signing of the agreement, the members of the consortium have begun exploring and screening technical options. If a potential technical solution is identified, the parties will determine whether to pursue joint development project(s), including R&D activities

that could include a demonstrator for proof of concept in the case of base chemicals. "They are working very hard together, but it is too early to talk about specifics," says Lia Voermans, director of Innovation Strategy, Brightlands Chemelot Campus.

Already in 2018, BASF SE (Ludwigshafen, Germany; www.basf.com) had begun its own five-year research project to develop the world's first electrical heating concept for steam crackers. When the concept was first publicized at a press event in January 2019, Kiara Kochendörfer, the project leader for clean high-temperature processes, pointed out that the switch from fossil-fuel-fired cracker furnaces to the E-Furnace using renewable energy (solar, wind, battery) would cut CO_2 emissions by 90%. BASF is working together with partner Linde Engineering (Munich, Germany; www.linde-engineering.com).

Because the concept is new, the researchers are "entering unknown territory of high Ampere [current] and low voltage," explained Kochendörfer. Among the challenges are metallurgical — finding the right materials for the cracker coils that can handle operation at 1,000°C.

Meanwhile, progress continues on the development of a completely new cracker concept from Coolbrook Oy (Helsinki, Finland; www.coolbrook.fi). The patented RotoDynamic Reactor (RDR) technology has the potential to improve ethylene yields by 34% compared to conventional furnace-based naphtha crackers, according to Coolbrook CEO Harri Johannesdahl.

RDR is a regenerative turbomachine (Figure 3) consisting of three axial blade rows (stator, rotor and diffuser) and a toroidal vaneless space that circumferentially connects the blade passages, which allows the regenerative heating of the working fluid, explains Johannesdahl. The fluid is accelerated in the stator, and the mechanical energy is converted to internal energy of the fluid by the rotating blade row, thereby increasing the temperature and pressure of the fluid. Unlike conventional crackers, which heat the fluid from outside the furnace, the RDR is heated from within the reactor. As a result, the residence time inside the RDR is just 0.02–0.04 s, which is about one tenth of that achieved in conventional crackers, says Johannesdahl. In this short time, the high temperature (over 900°C) and pressure (1–3 barg) reached in the RDR efficiently pyrolyzes naphtha with a high ethylene yield (over 43%) — 34% higher than conventional crackers, he says.

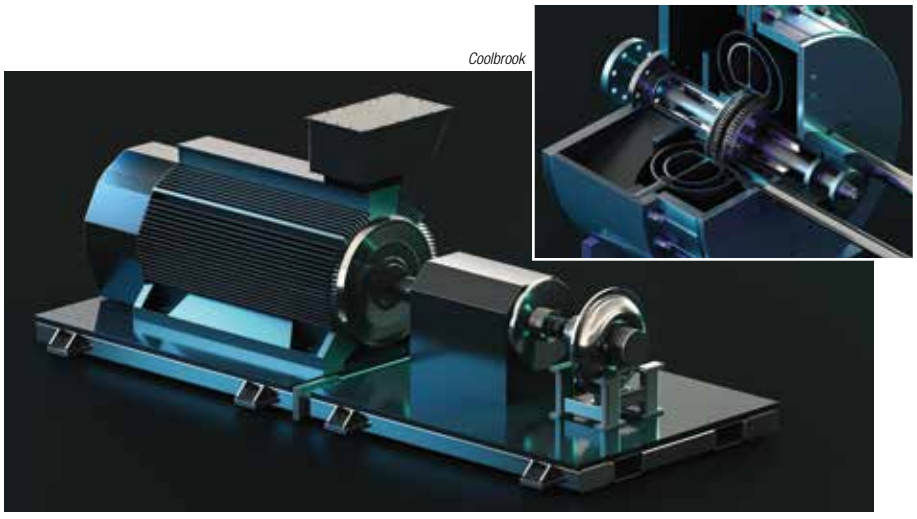


FIGURE 3. Coolbrook's RotoDynamic Reactor has the potential to improve ethylene yields by 34%, compared to furnace-cased naphtha crackers. The regenerative turbo machine (closeup, upper right) can be motor driven using renewable electricity, thereby reducing CO_2 emissions from the cracking process by 70%

The company recently completed a two-year project (*Chem. Eng.*, May 2017, p. 9), and is now investing €12 million to scale up the reactor from 90 kg/h (the R&D reactor) to 500 kg/h, with startup planned for this fall. The new plant, together with the company's R&D hub, have now moved to Brightlands Chemelot Campus.

The current RDR eReactor design will be driven by an electric motor, thus permitting electrification of the cracking process, says Johannesdahl. The yield benefit remains what was reported in 2017, says Johannesdahl, but now the CO_2 emissions from the cracking process are reduced by 70% and energy consumption is 21% less, he says.

"As Coolbrook's revolutionary RDR technology has multiple benefits compared to any known technology in use or under development, all the major petrochemical companies, including 'Cracker of the Future' consortium, have expressed their interest on this technology," says Johannesdahl. "Since RDR can be a breakthrough technology in the battle against the CO_2 emissions, Coolbrook is working hard to get a large cluster of different stakeholders behind its technology to guarantee as fast and efficient market entry as possible," he says.

Waste plastics as feedstock

"Various trials are planned to use recycled plastic waste as cracker feedstock," says TechnipFMC's Middleton. "The limitations on the extent to which this can be achieved are mainly associated with the logistics of reclaiming recycled plastics and the energy required for recycling by pyrolysis," he cautions. "Another issue that is not yet fully developed is the range of contaminants that may be present in the recycled plastics, which can have an adverse effect on cracker product quality and catalyst life."

"In Europe and SE Asia, the use of such recycled feed is expected to become more common in the next few years, but the logistics of waste collection is expected to mean that this will only form a relatively small proportion of cracker feedstock," says Middleton.

For example, as part of its ChemCycling project, BASF SE (Ludwigshafen, Germany; www.basf.com) is already piloting the manufacturing of some products based on chemically recycled plastic waste (*Chem. Eng.*, March 2019, pp. 14–18). BASF feeds oil derived from plastic waste into its Verbund production site. BASF gets this feedstock for the pilot products from the partner Recenso GmbH (Remscheid, Germany; www.recenso.eu). The first batch of this oil was fed

into the steam cracker at BASF's site in Ludwigshafen in October 2018.

Recenso operates an industrial-scale pilot facility that uses its catalytic tribochemical conversion (CTC) process to convert municipal waste into a liquid oil. In the process, metals, stone and wet materials are first separated from the waste. The resulting material, predominantly plastic films, foils, paper and some biomass, is then fed to a slurry reactor, where it is heated by friction to around 350°C, and catalytically cracked into a pyrolysis gas. The vapor is condensed into a liquid oil that can be used as a fuel, or as a feedstock to a steam cracker, as is being done at BASF.

In a related project, Dow last August reached an agreement with Fuenix Ecogy Group (Weert, the Netherlands; https://fuenix.com), for the supply of pyrolysis oil feedstock, which is made from plastic waste (*Chem. Eng.,* November 2019, pp. 12–14). The feedstock is being used to produce new polymers at Dow's production facilities at Terneuzen, the Netherlands. The polymers produced from this pyrolysis oil will be identical to products produced from traditional feedstocks, and as such, they can be used in the same applications, including food packaging.

Meanwhile, a process that directly converts waste plastic into gaseous building blocks is being developed by a research group at Chalmers University of Technology (Gothenburg, Sweden; www.chalmers.se). This gasification process avoids the need to first convert plastic waste to a pyrolysis oil that can be fed to an existing steam cracker, and instead, directly cracks the plastic waste into gaseous building blocks that can operate in parallel with existing crackers to make new plastics. The new process could transform today's plastic factories into recycling refineries, within the framework of their existing infrastructure, according to the researchers.

The process is essentially a type of steam cracking of the waste plastics. Using experience gained from a first-of-its kind plant that gasified biomass into biomethane, the group has been working to apply this technology — a dual fluidized-bed (DFB) system — for steam cracking of waste plastics.

"Through finding the right temperature — which is around 850°C — and the right heating rate and residence time, we have been able to demonstrate the proposed method at a scale where we turn 200 kg of plastic waste an hour into a useful gas mixture, which can then be recycled at the molecular level to become new plastic materials of virgin quality," says Henrik Thunman, professor of Energy Technology.

The experiments — reported in a recent issue of *Sustainable Materials and Technologies* — were carried out at the Chalmers Power Central facility in Gothenburg, using a DFB system. The first commercial use of a DFB-type system has been the fluid catalytic cracking (FCC) reactor in the petroleum-refining industry, which uses gaseous feedstocks and consists of two interconnected circulating fluidized beds, explains Teresa Berdugo Vilches, a postdoctoral researcher in the Dept. of Space, Earth and Environmental Energy Technology, at Chalmers. "The DFB system developed at Chalmers consists instead of a bubbling bed connected to a circulating fluidized bed, and it is designed to handle solid feedstocks. It differs from a conventional circulating fluidized bed in the fact that it has two reaction environments: the bubbling bed that serves as a cracking reactor of solid plastic particles, and the circulating fluidized bed that serves as a combustor, she explains. "It was developed for gasification of woody biomass and it has now been applied for the cracking of plastics."

"We are now moving on from the initial trials, which aimed to demonstrate the feasibility of the process, to focusing on developing more detailed understanding," says Thunman. This knowledge is needed to scale up the process from a few metric tons of plastic a day, to hundreds of metric tons. That is when it becomes commercially interesting," says Thunman.

The process is said to be applicable to all types of plastic that result from our waste system, including those that have historically been disposed in landfills or at sea. ■

Gerald Ondrey

Optimized Mixing

Improved equipment and controls, as well as continuous mixing, improve efficiency

IN BREIF

Optimization is imperative for today's chemical processors who strive to remain competitive by providing higher quality products at lower costs in a more timely fashion. And mixing operations are ripe for optimization, as one of the greatest obstacles to achieving efficient mixing is the often significant time it takes to reach the required homogeneity. Because extended mixing time decreases energy and process efficiency, equipment providers are improving performance via more thorough testing, mixer designs that combine steps and the addition of improved control and monitoring technologies. Meanwhile, some chemical processors are making the leap from batch to continuous mixing operations, where possible, to further optimize these processes.

Ekato

FIGURE 1. For complex processes where agitation is combined with other processes, a combined approach may be suitable, such as in a photochemical reactor where light is used to initiate a chemical reaction. Ekato's photochemical reactor, for example, enables users to run chlorination reactions at very mild reaction conditions with yields above 99.9%

"Poor agitation in process or blending tanks is one of the major problems in industry," says Hans-Joachim Jacob, process and application engineer with Ystral GmbH (Ballrechten-Dottingen, Germany; www.ystral.com). "It expands process time, blocks the equipment and the operators for long amounts of time, limits the batch size and reduces the possible quality," he says.

"When looking into a process tank and watching material circulating with slow movement from outside to center, you know the mixing time is too long," continues Jacob. "A batch recipe with 30 minutes mixing at the end of the batch is an indication that the process cannot be effective. If an agitator cannot blend a tank homogenously in three minutes, it cannot blend it in any acceptable time."

Further, when adding components into such a tank, it creates local over-concentrations and zonal mismatches in the formulation, since the turnover of the product simply takes too long. "You would have to add the additives extremely slowly to avoid that, which is not acceptable," says Jacob. "Processors must understand that permanent homogeneity has to be guaranteed by fast and proper mixing equipment. This way, you avoid local over-concentrations and finish the batch in the shortest time."

Testing and design capabilities

In order to properly design mixing equipment so it achieves optimized and efficient mixing, it is necessary to fully understand the physical and chemical processes that are occuring in the vessel, says Wolfgang Last, vice president and head of research and development with Ekato Rühr- und Mischtechnik GmbH (Schopfheim, Germany; www.ekato.com). "Is the goal to suspend a solid matter homogenously or is there a complex chemical gas/liquid reaction where a solid catalyst is used? This then takes us to the question of whether there are limiting factors within the reaction. What kind of reaction time or yield has to be achieved in order to reach the required output? In a lot of cases, the physical properties like viscosity or density are not clearly known throughout the entire process."

For this reason, equipment manufacturers, like Ekato, hold tests in a laboratory facility or with laboratory-scale equipment at the processor's site. "Once we use testing

to answer these basic questions, it brings us to scaleup where a sufficient degree of geometric similarity is required. Mechanical aspects also need to be evaluated, as mixing systems must be designed not only with respect to strength, but also to ensure that resonance does not occur," says Last.

Last says profound CFD (computational fluid dynamics) is used to understand the detailed flows in the vessel and a FEM (finite element method) simulation is used to analyze the forces on the equipment. "In a lot of cases it is not only the blade design that is the issue, but also the feed-and-drain points that can be improved significantly by testing and studying the process and equipment using these methods."

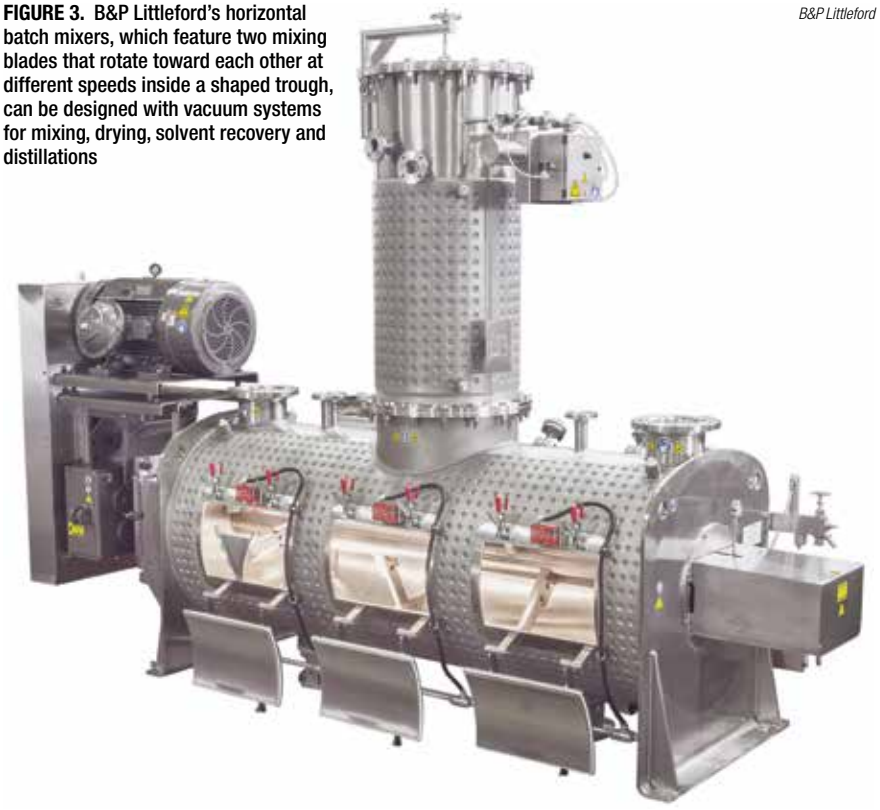
He stresses the importance of working with processors, as well as modern testing, design and production technologies. "We have been successfully developing solutions together with our customers that meet the increasing demands for chemical products that are economically efficient by using modern design tools and new production technologies to generate up-to-date types of impellers for optimized mixing," he says. "Only an integrated, case-by-case analysis of a mixing problem will provide the best technical solution with regard to investment and operating costs, as well as energy and resource efficiency. This integrated approach combines a straightforward definition of the requirements, tried and tested experimental techniques, new numerical methods and practical experience with respect to design and scaling up to full-scale production."

Ystral

FIGURE 2. **In Ystral's Dispermix, the outer part of the liquid stream is forced through the dispersing slots. Using this machine, the dissolving time of materials can be reduced by 90% since the dispersion prevents agglomeration and simultaneously reduces the particles size of the granules**

Combined functions

In some cases, what these methods are uncovering is that a combined approach is the most efficient solution. "For example, in complex customer processes where agitation is combined with other processes, a combined approach may be needed, such as in a photochemical reactor where light is used to initiate a chemical reaction," says Last. "Our photochemical reactor enables customers to run chlorination reactions at very mild reaction conditions with



B&P Littleford

FIGURE 3. B&P Littleford's horizontal batch mixers, which feature two mixing blades that rotate toward each other at different speeds inside a shaped trough, can be designed with vacuum systems for mixing, drying, solvent recovery and distillations

yields above 99.9%" (Figure 1).

Ystral's Jacob agrees that certain applications benefit from combined operations. "Normal jet stream mixers are famous for their combination of an effective laminar macro mixing of the whole tank with a turbulent micro mixing concentrated just inside the mixing head," he says. "This provides a completely homogenous distribution in seconds." However, products that form agglomerates after addition, such as thickeners, and products that tend to re-agglomerate, such as ground sulfur, or cohesive ingredients, such as proteins, require a permanent, medium-shear dispersion. "In these cases, just turbulence is not enough. For these applications, a combination of mixer and disperser is the ideal tool," says Jacob. In Ystral's Dispermix, the outer part of the liquid stream is forced through the dispersing slots (Figure 2). Using this machine, the dissolving time of materials can be reduced by 90%, since the dispersion prevents agglomeration and simultaneously reduces the particle size of the granules. Real high-shear dispersion in combination with the advantages of jet stream mixing is provided, making the Dispermix suitable for the production of emulsions or very fine particle dispersions.

Charles Ross & Son Company

FIGURE 4. The abilities of the mixing equipment control systems have improved and include more features and more connectivity at lower costs, allowing operators better control of the mixer

Shawn Hearn, product manager for mixing systems at B&P Littleford (Saginaw, Mich.; www.bplittleford.com), agrees that this combined-step approach is often more efficient. "We try to do as many steps of the required function in one vessel as is possible, which creates efficiency advantages," he says. For example, B&P Littleford's horizontal batch mixers, which feature two mixing blades that rotate toward each other at different speeds inside a shaped trough, can be designed with vacuum systems for mixing, drying, solvent recovery and distillations (Figure 3). "The batch mixer can combine a lot of steps. For example, there is a pre-mixing function that mixes material A to material B, then it is possible to add a liquid solution, which may contain the active ingredient, to the base compound. In the same vessel, we can strip that liquid vehicle away, leaving just the active ingredient, via heating, drying or vacuum systems. It is inherently more efficient and creates better batch-to-batch consistency," says Hearn.

Improved control technologies

Even with improved designs and combined functions, optimized mixing requires very precise feeding and blending of ingredients without over- or under-working materials, while putting in just enough energy per batch. Achieving this type of optimization requires advanced monitoring and controls. "If processors can monitor the speed of the mixer and realize when the process is at the point where it doesn't require as much mixing, they can use controls to reduce the speed, which will provide a tremendous savings in energy, reduce time in the process and, often, improve finished product quality," says Kevin Walsh, product line director for mixing technologies, with NOV Process and Flow Technologies (Dayton, Ohio; www.nov.com/pft).

Advanced monitoring and control technologies are also helpful when it comes to documentation, according to Ken Langhorn, vice president of sales with Charles Ross & Son Company (Hauppauge, N.Y.; www.mixers.com). "Processors often have the same parameters in each batch and use recipe software for this, and all the process conditions — time, speed, temperature and so on — are documented and controlled very carefully. Control and monitoring technologies, along with documentation, have had a great impact on efficiency, batch-to-batch consis-

Readco

FIGURE 5. Readco's Continuous Processor focuses continuous mixing on a small amount of material over a short period of time, allowing processing of the same amount of material in a similar timeframe as a comparable batch mixer

tency and product quality," he says. "While the mixing elements themselves haven't changed much, the abilities of the control systems have improved and now include more features and more connectivity at lower costs, allowing operators to have a finger on the pulse of whatever is going on inside that mixer" (Figure 4).

Today's technologies, says Langhorn, allow processors to run mixers from a smart phone or PC using Wi-Fi. "With these capabilities, it ensures that the equipment is mixing for the same amount of time, under the same conditions and can prompt operators to add a certain quantity of materials at a certain time to create better consistency, batch to batch."

Digitalization, adds NOV's Walsh, is the next step on the road to mixing operation optimization. "Processors are using digitalization to improve the uptime of their mixers, as well. This includes using vibration and temperature sensors, speed detectors and liquid-level indicators on vessels to monitor the health of the equipment. This digital monitoring allows users to get more insight into the health of the mixer and ties back into energy efficiency, also.

"If they know the process requirements aren't as rigorous, digitalization allows them to identify how much to reduce the speed and when to do so, optimizing the process, while reducing energy use," he explains. NOV offers GoConnect, which encompasses hardware, monitoring, alarming, data analysis and the ability to make reports.

Moving to continuous mixing

While continuous mixing is not suitable for chemical processors who use a wide variety of recipes, some processors are moving from batch to continuous mixing because it can, in the right situations, provide a significant process improvement, says Rene Medina, managing director with Gericke USA, Inc. (Somerset, N.J.; www.gerickegroup.com).

David Sieglitz, president of Readco Kurimoto LLC (York, Pa.; www.readco.com), agrees: "Many times the upstream and downstream processes are continuous with a batch mixer in the middle of the process line. In this scenario, the batch mixer becomes the bottleneck of the process; however, using continuous mixing ensures a truly automated process line without interruption or downtime. "This is because continuous mixing trades time for mixing intensity," he says. "What may take hours to complete in a batch process can often be accomplished in

minutes continuously."

Sieglitz says his company's Continuous Processor focuses continuous mixing on a small amount of material over a short period of time. "By doing so, we successfully process the same amount of material, or more, in a similar timeframe as a comparable batch mixer. We can do this with a smaller motor, consuming less energy, and with a smaller footprint, saving production floor space. Typically there is also significantly less waste using the continuous mixing" (Figure 5).

In the past, processors shied away from continuous mixing, even though it is typically more efficient, because batch processing provides the ability to make ingredient changes and adjustments to improve the final product when something is out of specification; whereas with continuous processing, the recipe has to be almost perfect because it's difficult to go back and change things once the process has begun, or to make adjustments if a raw material has variables from day to day. However, advanced monitoring and control technologies have made continuous mixing more feasible.

"Thanks to improved monitoring and controls, processors are not as reluctant to move from batch to continuous mixing," says Gericke's Medina. "During continuous mixing, we can now monitor the feeding and mixing online, in real time, to improve the quality and make the system more reliable, ensuring consistent and correct product." The company's dedicated, continuous GCM mixer offers state-of-the-art mixing with automation that allows for easy adjustments to vary products, recipes, outputs, residence times and energy levels.

Readco Kurimoto's Sieglitz also stresses the importance of control in continuous mixing operations. "Continuous mixing requires an accurate feed stream to ensure consistent quality product. This is accomplished by specifying the proper type and size powder feeders and liquid pumps. Precise control of the feed streams is also important. We achieve this using loss-in-weight technology. A simplified explanation of this is that the individual feed streams are accurately controlled by monitoring and metering using load cells with a feedback loop to the controller, which increases or decreases the motor speed of the pump or feeder to ensure the feed remains consistent, regardless of head pressure or other external variables.

"Making consistent product is imperative in the chemical processing industry and continuous mixing eliminates batch-to-batch variations that are inherent in that process," says Sieglitz. "In addition, there are many other factors that drive chemical processors to continuous processing. Some of these include increased quality and safety, while others are interested in reducing floor space, process steps, waste, environmental impact, labor, work in process and cycle time." ■

Joy LePree

Focus on Analyzers

Raman spectroscopy capability with bioreactor platforms

BioPAT Spectro (photo) is a Quality by Design (QbD) tool for use with this company's ambr automated micro and mini bioreactor systems and with Biostat STR single-use production bioreactors. The new tool offers access to Raman spectroscopy analysis in high-throughput process development, supporting faster Raman model building and accelerating scaleup into commercial manufacturing. Raman spectroscopy is non-invasive and can measure multiple analytes, making it suitable as a process-analytical technologies (PAT) method for process control and monitoring of cell cultures. The new BioPAT Spectro tool, can be retrofitted into ambr 15 cell-culture and ambr 250 high-throughput systems. It enables quick and simple sampling for integrated at-line analysis of a large number of analytes by Raman spectroscopy in a design-of-experiments (DoE) approach. — *Sartorius AG, Göttingen, Germany*
www.sartorius.com

Switch for analyzer verification in hazardous environments

The Model FS10A (photo) is a universal flow switch and monitor designed for gas and liquid process-analyzer-sampling systems. The FS10A is a fast-responding, highly repeatable sensor that installs easily into a standard tube tee fitting or the SP76 (NeSSI) modular manifold. The FS10A utilizes proven thermal-dispersion flow-measurement technology with this company's proprietary equal mass sensing to achieve outstanding sensitivity and repeatability. The instrument's wetted parts are corrosion-resistant 316L stainless steel with Hastelloy C-22 sensor tips. — *Fluid Components International, San Marcos, Calif.*
www.fluidcomponents.com

Raman spectroscopy products with advanced features

Last September, this company unveiled the next-generation DXR3 family of Raman spectrometers and microscopes (photo). This new generation features advanced imaging and workflow capabilities to provide users with Raman analysis at their required speed. Advanced particle analysis and 3D confocal visualization software delivers answers faster while the automatic *x*-axis calibration eliminates time-consuming manual calibration. Additionally, the DXR3 family is more flexible with an expanded offering of lasers and detectors. The DXR3 family of Raman products accelerates productivity in a broad range of industries. — *Thermo Fisher Scientific, Hillsboro, Ore.*
www.thermofisher.com

These fixed-gas analyzers are now CSA-certified

The Landtec Biogas 3000 and the Biomethane 3000 (photo) fixed-gas analyzers have received certification by the CSA Group. The CSA safety mark signifies that the equipment has been independently tested for compliance with North American and Canadian safety standards. The two analyzers are a.c.-powered products that measure biogas and landfill gas, and can be installed in potentially explosive areas. The CSA certification ensures that the equipment can be safely used and will not be the cause of an explosion. These products also have ATEX and IECEx certifications for use in potentially explosive atmospheres. — *Q.E.D. Environmental Systems, Inc., Dexter, Mich.*
www.qedenv.com

Water analyzer quantifies total hydrocarbons and VOCs

The Model 204 Hydrocarbon VOC in Water Analyzer (photo, p. 24) has an enhanced method of analytically quantifying total hydrocarbons and volatile organic compounds (VOCs) in cooling towers, heat exchangers, holding ponds, run-off water and wastewater. Utilizing an exclusive sample-transfer stripper and solid-state sensor, the water analyzer measures oil and VOCs directly in the water, as opposed to the air around the water — a method that misses VOCs and results in non-alarm

Sartorius

Fluid Components International

Thermo Fisher Scientific

Q.E.D. Environmental Systems

Note: For more information, circle the 3-digit number on p. 66, or use the website designation.

Analytical Systems Keco

Micromeritics Instrument

Ametek Process Instruments

Electro-Chemical Devices

Servomex Group

events. The 204 also measures very low levels (parts per billion) to detect a small leak very early before it becomes an environmental issue. — *Analytical Systems Keco, Houston*
www.liquidgasanalyzers.com

Characterize next-generation adsorbants with this analyzer

The Selective Adsorption Analyzer 8100 (SAA-8100, photo) is a flexible gas-delivery and management system for the precise characterization of adsorbent performance under process-relevant conditions. Combining this company's knowledge of gas adsorption with the tried-and-tested technology of PID Eng and Tech, a recently acquired company that provides microreactor and pilot-plant technology, the SAA-8100 delivers reliable, selective adsorption data for gas or vapor mixtures by mass balance. A highly efficient tool for evaluating the performance of next-generation adsorbents, the SAA 8100 is particularly valuable for researchers working in fields such as gas separation, storage and purification, carbon dioxide capture and energy storage. — *Micromeritics Instrument Corp., Norcross, Ga.*
www.micromeritics.com

Process mass spectrometer for realtime gas analysis

The StreamPro (photo) is a field-proven system for critical process analysis and control applications. Because mass spectrometry is a very rapid analytical method that allows for the analysis of multiple components in seconds, the StreamPro quickly provides the user with actionable data. Applications for the StreamPro include monitoring for any number of analytes (C1–C8, H_2, N_2, CO_2, CO, O_2, VOCs and other components) in a broad range of applications (pharmaceutical, hydrocarbon processing, research and design and process development). Real-time process monitoring of multiple components is straightforward with the StreamPro's Process 2000 software. Complex overlapping spectra are handled automatically, with data output provided directly in concentration units. Different calibration and analysis methods can be assigned to each sample port. — *Ametek Process Instruments, Pittsburgh, Pa.*
www.ametekpi.com

This fluoride analyzer preconditions samples

The CA900 Analyzer (photo) delivers continuous, accurate measurement of fluoride in aqueous solutions to support a wide range of municipal water and industrial plant process and effluent treatment applications. Its all-in-one design eliminates the need for additional water sample pretreatment equipment, reducing installation complexity, maintenance tasks and lifecycle costs, says the company. The CA900 Analyzer operates in challenging environments from 0 to 50°C (32 to 120°F), and covers a wide measurement range from 0.1 to 200 mg/L (0.1 to 200 parts per million; ppm). It features accuracy of ±100 parts per billion (ppb), or 5% of measurement, or whichever is greater and repeatability of ±2% for consistent measurement. — *Electro-Chemical Devices, Anaheim, Calif.*
www.ecdi.com

High-temperature oxygen transmitter is SIL 2 compliant

This company now offers SIL 2 safety compliance for the 2222H transmitter unit of its Servotough OxyExact 2200 oxygen gas analyzer (photo). A high-precision oxygen analyzer designed for use in hazardous area installations, the OxyExact utilizes the company's patented, field-proven, non-depleting Paramagnetic sensing technology for a highly accurate, repeatable oxygen measurement. Using an intelligent three-enclosure system to ensure safe operation, it measures enriched oxygen (up to 100% O_2) in potentially flammable sample gases at pressures up to 45 psia. This system dramatically reduces ongoing costs by removing the need for pre-sample drying. Used in process control applications where high-temperature, high-performance oxygen measurements are required, the OxyExact is ideal for use in a range of hydrocarbon processing applications. — *Servomex Group Ltd., Crowborough, U.K.*
www.servomex.com

Hybrid laser-based gas analyzer for CEMs

The new Rosemount CT4400 continuous gas analyzer (photo) is the said to be the world's first purpose-built quantum cascade laser (QCL) and tunable diode laser (TDL) ana-

lyzer designed to help plants reduce ownership costs and report emissions accurately in environmental monitoring applications. The system measures standard components, such as NO, NO_2, SO_2, CO, CO_2, and O_2. Optimized for cold and dry applications running at ambient pressure, the CT4400 analyzer offers the benefits of QCL/TDL technology, including high sensitivity, accuracy, improved stability and low-drift performance in a configuration that allows fast, easy integration into existing plant infrastructure. Because the system can hold up to four laser modules, it can measure up to seven application-specific gas components simultaneously, providing great flexibility in continuous emissions monitoring systems (CEMs) applications. — *Emerson Automation Solutions, Shakopee, Minn.*

www.emerson.com

Emerson Automation Solutions

New coatings analyzer for ultrathin layers

The new FT160 XRF analyzer has three base configuration options for the analysis of nanometer-scale coatings. Following the introduction of the new FT160 series in Japan, this company now sells and services the FT160 series coatings analyzers in China, North America, Europe, Middle East and Africa. This latest generation of coatings analyzers has been designed to meet the challenges of measuring ultra-thin coatings on small features. The FT160 is a benchtop EDXRF (energy dispersive X-ray fluorescence) analyzer with powerful software and hardware created to deliver high sample throughput with quality results achieved by any operator. Designed to play a key role in production quality control, the FT160 series measures a wide range of applications in the semiconductor, circuit board and electronics components markets. — *Hitachi High-Tech Analytical Science Corp., Westford, Mass.*

www.hitachi-hightech.com

An ATEX-certified Raman analyzer is now available

This company has received ATEX and IECEx certification for its OPIS 35 laser accessory (photo). The certification is in accordance with the IEC 60079 standard, and authorizes the HyperFlux PRO Plus Raman analyzer for operation in ATEX Zone 0 when both products are used together. In the certified configuration, the OPIS 35 and HyperFlux PRO Plus are placed in a safe location with fiber optic interconnections to the Raman probe in the hazardous location. The OPIS 35 regulates the HyperFlux PRO Plus laser output to guarantee that no greater than 35 mW of laser power can enter the hazardous location. In accordance with Class 3B laser regulation, the OPIS 35 provides ATEX/IECEx certified signaling. — *Tornado Spectral Systems, Toronto, Canada*

www.tornado-spectral.com

Gerald Ondrey

Tornado Spectral Systems

Nuclear Magnetic Resonance Spectroscopy

Department Editor: Scott Jenkins

Nuclear magnetic resonance (NMR) spectroscopy is an analytical chemistry technique used to elucidate molecular structure and help identity unknown compounds. It is a powerful research tool used for quality control, reaction monitoring, purity analysis and other functions.

Nuclear spin

The properties of subatomic particles give rise to spin, a form of intrinsic angular momentum that can be represented by imagining the particles as tiny spheres spinning on their axes. Although nuclei don't actually spin, the concept can help explain the principles underlying NMR.

In atoms where the total number of neutrons or protons is an odd number, the nuclei possess an overall spin. For example, ^{12}C has a spin of 0, while the isotope ^{13}C (6 protons, 7 neutrons), has nonzero spin. NMR spectroscopy only detects nuclei with nonzero spin. Examples include the following: ^{13}C, ^{1}H, ^{15}N, ^{19}F, and ^{31}P.

Magnetic fields

Behaving as spinning charged particles, each NMR-active nuclei generates its own magnetic field, which is oriented in a particular direction. Normally, the magnetic moments generated by a sample are oriented randomly in all possible directions. But in an externally applied magnetic field, the nuclei align their magnetic fields with the applied field — either in the same direction of the applied field (known as the alpha spin state), or aligned against it (beta spin state).

Alpha state is lower energy (more stable and more common) than beta, and the difference between the two is proportional to the strength of the external magnetic field. The strength of an NMR magnet determines spectral resolution. Modern superconducting magnets routinely reach magnetic fields greater than 11 Tesla.

Resonance and relaxation

To generate an NMR spectrum, a sample is placed between the poles of a superconducting magnet and is irradiated with bursts of radio-frequency energy. The radio waves are absorbed by the nuclei when the frequency of the radiation matches the frequency at which the nuclei precess around its axis. When the energy is absorbed, the protons flip from the alpha state into the beta (higher energy) state. When this occurs, the nuclei are said to be in resonance.

When a nuclei returns to its original state from an excited energy state, it is said to undergo "relaxation." As the nuclei relax, they emit electromagnetic signals whose frequencies can be detected by an NMR spectrometer. The signals (peaks) are plotted on a graph of frequency versus intensity.

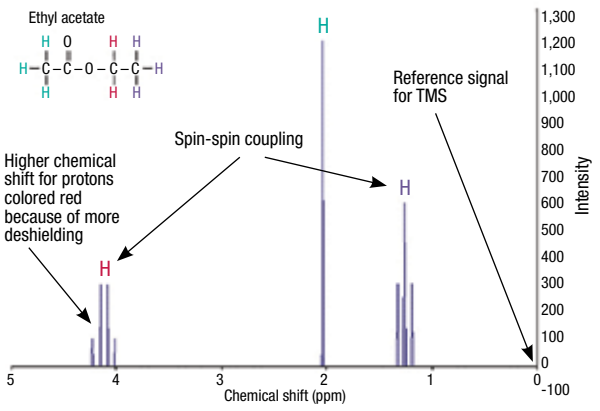


FIGURE 1. An example H-NMR spectrum for the compound ethyl acetate shows different chemical shifts for the three sets of protons in the compound, each having a different electronic environment

Chemical shift

The precise resonant frequency at which the flip from lower to higher energy occurs depends on the effective magnetic field at the nucleus. And the effective magnetic field is influenced by electrons around the nucleus, which shield the nucleus from the applied magnetic field. In general, the more electronegative a nucleus is, the less shielding occurs and the higher the resonant frequency. In this way, the chemical environment surrounding the nucleus, and hence, the chemical structure of a compound, can be probed.

In ^{1}H-NMR, each group of chemically equivalent protons (protons with the same electronic environment) in a molecule gives rise to a separate signal, which appears at a slightly different resonant frequency. These different frequencies are expressed as shifts away from a reference signal, which is set to zero. For ^{1}H-NMR, tetramethylsilane (TMS) is used as the reference signal, and the distance from the reference is called a chemical shift (Figure 1).

The effective magnetic field experienced by a nucleus also depends on the orientation of neighboring nuclei. This effect, known as spin-spin coupling, results in the splitting of signals into two or more lines. This indicates the number of chemically bonded nuclei near the observed nuclei. Splitting patterns allow experimenters to determine structural information.

Applications

The following are examples of industrial applications for NMR.

- ***Pharmaceuticals.*** NMR is used for drug discovery, structural confirmation and identifying pharmaceutical effects within natural products
- ***Biofuels.*** NMR is used to characterize biodiesel, such as quantifying its percentage in fuel mixtures
- ***Polymers.*** NMR can help observe polymerization reaction completeness and uniformity, qualify relative composition, identify stereoisomers, and determine modular number, molecular weight and polydispersity index
- ***Process analytical technology.*** NMRs can act as digital detectors for process-line reaction monitoring
- ***Catalysts.*** NMR spectroscopy can help characterize catalysts deposited on substrates
- ***Petrochemicals.*** NMR provides information on the identities and characteristics of fluids present in a mixture, and their compositions and viscosities ■

Production Process for Neopentyl Glycol

By Intratec Solutions

Neopentyl glycol (NPG; 2,2-dimethylpropane-1,3-diol) is an industrially important and versatile diol, mainly employed as a building block for polyesters and polyurethanes. NPG imparts desirable properties to its derivatives, including low color, good weathering and chemical resistance, and high thermal and hydrolytic stability.

This glycol is a crystalline solid at room temperature that is highly reactive and colorless to white in color. It has good solubility in water, alcohols, ethers, ketones and toluene. As a typical glycol, it can undergo reactions such as esterification, etherification, condensation and oxidation.

The process

The process described here is an aldol reaction followed by hydrogenation (Figure 1). It comprises three major sections: (1) aldol condensation; (2) hydrogenation; and (3) purification.

Aldol condensation. An aldol reactor is fed with an aqueous solution of formaldehyde, isobutyraldehyde and triethylamine. In such a reactor, an aldol condensation reaction between isobutyraldehyde and formaldehyde is carried out in the presence of triethylamine catalysts. The output from the aldol condensation reactor, containing crude hydroxypivaldehyde (3-hydroxy-2,2-dimethylpropanal) intermediate, is submitted to extraction with octanol and distillation for the recovery of a purified hydroxypivaldehyde (HPA).

Hydrogenation. The purified intermediate is fed to a loop-type reactor, along with hydrogen gas. There, a reaction between hydroxypivaldehyde and hydrogen takes place, in the presence of Raney-nickel catalysts. This type of hydrogenation reaction yields a mixture containing crude NPG, which is then submitted to a saponification step. In the saponification, the precursors still present in the hydrogenation product are converted to NPG in the presence of a 50 wt.% sodium hydroxide solution.

Purification. In this section of the process, the product stream rich in NPG and a stream containing residual NPG are fed to an extractor, where water is used as solvent to extract NPG. The aqueous phase from the extraction is fed to a distillation column, which further separates a mixture of NPG and water from salt impurities. The NPG-and-water mixture is fed to the last column, which further purifies the main product. High-purity NPG withdrawn from column bottom is routed to a finishing step and finally stored.

Production pathways

NPG is commercially produced by the aldol reaction of formaldehyde and isobutyraldehyde, followed by the reduction of the intermediate hydroxypivaldehyde, which can be made with either excess formaldehyde (crossed Cannizzaro reaction) or by catalytic hydrogenation of the aldehyde group (the most common process). These two possible routes are shown in Figure 2.

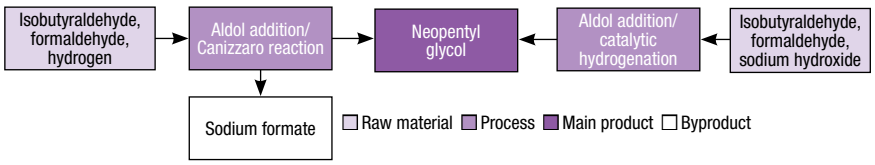


FIGURE 2. Two production pathways are available for NPG

Economic performance

The total operating cost (raw materials, utilities, fixed costs and depreciation costs) estimated to produce NPG was about $1,380 per ton of NPG in the second quarter of 2016. The analysis was based on a plant constructed in the U.S. with the capacity to produce 60,000 metric ton per year of NPG.

This column is based on "Neopentyl Glycol Production Process – Cost Analysis," a report published by Intratec. It can be found at: www.intratec.us/analysis/neopentyl-glycol-production-cost. ■

Edited by Scott Jenkins

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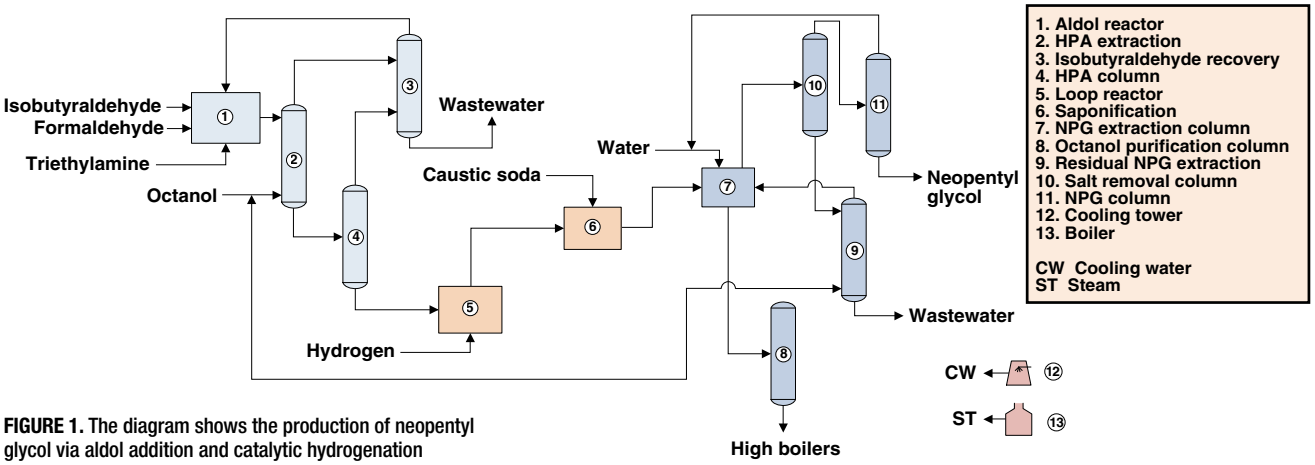

FIGURE 1. The diagram shows the production of neopentyl glycol via aldol addition and catalytic hydrogenation

Part 1

Principles of Agglomeration: Pelletizing Processes

Pelletizing, a tumble-growth agglomeration process, offers many potential benefits to processors handling bulk solid materials. This article provides an overview of how agglomerate pelletizing works and the important elements that must be considered

Chris Kozicki, Ron Eichhorn and Carrie Carlson
FEECO International

IN BRIEF

Pelletizing, a form of agglomeration (particle size enlargement) employed to produce a rounded granule, is a valuable operation when working with bulk solids. The technique offers a number of possible improvements to the handling, appearance, application and performance of a wide range of solids materials. The term "pelletizing" is often used interchangeably to refer to various types of agglomeration. This article refers only to pelletizing in terms of tumble-growth agglomeration, which is carried out using a disc pelletizer.

As a form of tumble-growth agglomeration, the pelletizing process is highly customizable and can be used to produce a spherical granular product to exacting specifications. The pelletizing process is most often carried out on a disc pelletizer, typically preceded by a preconditioning step in a pin mixer, and followed by a drying step, with additional process steps possible.

This article looks at the process of agglomerate pelletizing, including the potential benefits that can be realized through pelletizing, how the process works and the key principles behind a successful pelletizing operation.

FIGURE 1. Powders, such as the raw limestone shown here (left), can present difficulties in transportation and application. The pelletized form of limestone (right) can alleviate these difficulties

FIGURE 2. Synthetic gypsum is an example of a commonly pelletized solid material

PROCESSING AND MATERIAL BENEFITS

Pelletizing can be used to impart a number of improvements to both raw materials and end products. While not all products will exhibit all benefits, pelletizing can generally offer the following advantages:

Dust reduction or mitigation. When work-

ing with bulk solids in the form of powders or fines, pelletizing significantly reduces, (and in some cases, largely eliminates) dust. Because pelletizing produces a rounded granule, the potential for jagged edges to rub together and break down is decreased. Product integrity is therefore maintained, and material losses are kept to a minimum. Other issues associated with dust, such as health and safety hazards, are also eradicated.

Improved handling and application. Powders and fine materials can present various challenges during handling and application. These include difficulty in transportation, increased product loss, inaccurate and unpredictable application and flowability issues. Pelletized materials flow more readily, promote cleaner handling, and are less likely to become windblown on application (Figure 1). Transportation qualities are also improved, with reduced costs in some cases.

Control of particle properties. Pelletizing is perhaps most widely used as a means of particle engineering, allowing granules to be produced to exacting specifications. Various material characteristics can be fine-tuned to control active-ingredient-release properties or rate of reaction, improve product uniformity, enhance solubility, or even manage packing density and handling characteristics.

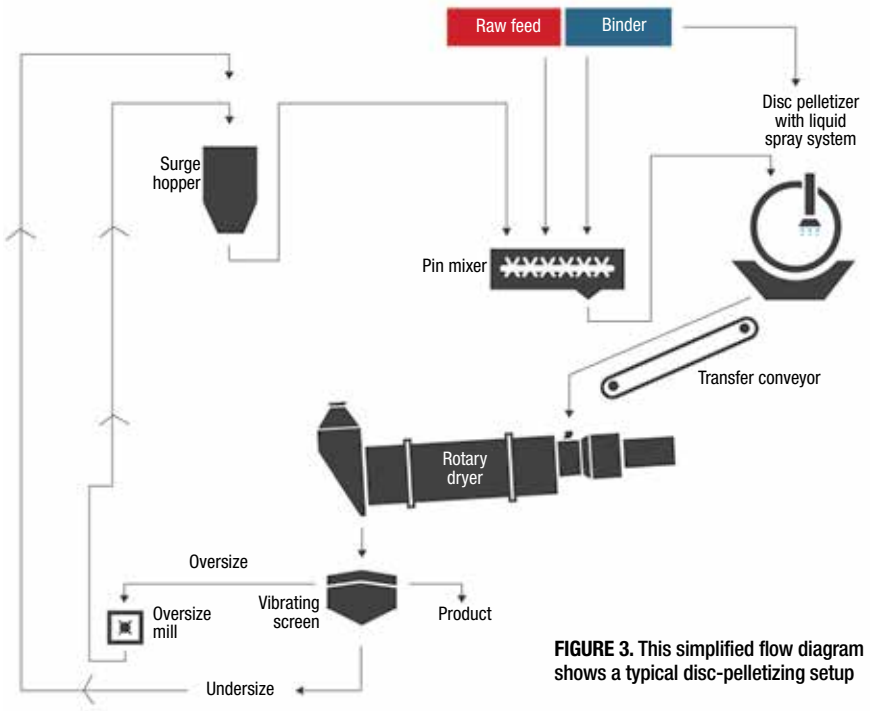

FIGURE 3. This simplified flow diagram shows a typical disc-pelletizing setup

FIGURE 4. The interior of this pin mixer, including the shaft-in-trough arrangement, can be seen during fabrication

FIGURE 5. Disc pelletizers, such as the one shown here, have a rotating disc mounted to a stationary base

When used as an intermediate step within a larger process, pelletizing is also used to control granule properties, such as heat transfer, porosity and density, in order to maximize performance during downstream processing.

Enhanced appearance. Pelletizing is frequently used as a means of improving product appearance. Granules can be produced to be round, smooth and uniform, transforming a regular product into a premium one, with improved flowability, uniformity in size, and less attrition. For this reason, pelletizing is widely used in the fertilizer and soil-amendment industries for high-value products.

Commonly pelletized materials. Pelletizing can potentially benefit any bulk solid material that presents handling, application, or performance challenges as a result of its particle characteristics. Solid materials that are frequently pelletized include the following:

- Crushed gypsum (natural or synthetic; Figure 2)
- Crushed limestone
- Nitrogen, phosphorus, potassium (NPK) fertilizers
- Soil amendments
- Flyash
- Iron ore
- Alumina
- Glass
- Silica
- Clays and ceramics
- Electric arc furnace (EAF) dust
- Soda ash
- Carbon black
- Biosolids/manures
- Titanium dioxide (TiO_2)
- Zinc oxide

PELLETIZING PROCESS

Pelletizing is a non-pressure (also referred to as tumble-growth or agitation) agglomeration technique, meaning that a liquid binder and tumbling action are employed to facilitate the formation of granules. This agglomeration technique differs from pressure-agglomeration methods, which use extreme pressure to cause powder materials to self-adhere into a desired form. Not

all solid materials are capable of agglomeration by pressure.

Primary steps

A typical pelletizing process setup is illustrated in Figure 3. While processes can vary, the most common approach to pelletizing can be broken down into three primary steps: preconditioning, pelletizing and drying.

Preconditioning. A preconditioning step is used to produce a homogeneous mixture of a dry or liquid binder and one or multiple feedstocks. It can also produce "seed pellets," or nuclei — small agglomerates that serve as the starting particle mass onto which fines will adhere.

Preconditioning is carried out in an industrial continuous mixer, most often a pin mixer — a horizontal, continuous mixer that uses an intense spinning motion to homogeneously pre-mix, densify, and possibly preform small agglomerates (Figure 4).

The mixer thoroughly combines the liquid and solid feed components into a homogeneous mixture. As the mixture moves down the length of the mixer, seed pellets begin to form. Upon reaching the predetermined retention time, seed pellets and preconditioned fines are discharged from the mixer and fed to the disc pelletizer.

Pelletizing. The disc pelletizer is a rotating disc mounted onto a stationary base (Figure 5). It is one of the most commonly used types of pelletizing equipment, because it produces a refined granule and offers a highly flexible approach to pelletizing. A number of variables, such as disc angle, speed, feed rate and others, can all be adjusted to control particle size and other characteristics.

FIGURE 6. Rotary dryers remove moisture from the agglomerated solids, allowing them to reach the desired crush strength

As the seed pellets are fed onto the rotating disc, the rotation carries pellets partially around the disc and through the feed and spray zones. The binder causes the growing pellets to become tacky, allowing them to pick up more fines as they tumble. This promotes a gradual rolling action that increases granule size by layering (coalescence) — a technique similar to rolling a snowball.

Because of the centrifugal force of the rotating disc, pellets naturally self-classify according to mass and size, with larger and heavier pellets falling sooner as they move closer to the discharge area. Once the pellets have reached the desired size, they are discharged from the disc and fed to a dryer.

Drying. Depending on the process goals and downstream processing, drying may or may not be used in a pelletizing process. The primary objective of drying is to reduce the moisture content of the material and solidify the bond between compo-

nents. In essence, the drying step "cures" the pellets into their final form. Without sufficient drying, pellets may not hold their shape, could clump together, or may even allow mold or bacterial growth to occur. The drying process also helps the end-product to reach the desired crush strength.

When carried out in a rotary dryer (Figure 6), drying has an added advantage: the rotational tumbling that occurs in the drum may further round and polish pellets.

Controlling particle characteristics. Achieving the desired matrix of end-product characteristics requires a careful balance of process and feedstock parameters. Material and binder feed rates, disc speed and angle, retention time and other variables, are all used to control the properties and overall quality of the end product.

The flexibility of agglomerate pelletizing allows operators to control a wide range of particle characteristics, and to produce an end product that meets a range of specifications for appearance and performance parameters, including the following:

- Green or wet strength
- Dry-pellet crush strength
- Amount of degradation and attrition
- Bulk density
- Solubility
- Flowability
- Particle size distribution (PSD)
- Moisture content
- Surface quality
- Temperature

Pelletizing process add-ons

Various other production elements can be integrated into the pelletizing process to further tailor the process to meet the unique application. Typical integrations are listed below.

Cooling. Depending on the product, a cooling step may be implemented after drying. Cooling helps to prevent product from caking during storage and allows material to be bagged immediately after production.

Coating. Coatings on the agglomerates are sometimes used to further improve granule performance, appearance, or handling characteristics in end products. A number of coating devices are available, with the coating drum being the equipment of choice for superior results.

Recycle. Disc pelletizers generally yield little recycle material, but a recycle circuit can still be beneficial in minimizing off-specification product. A recycle circuit consists of a screening system and mill for reducing oversized granules, as shown in Figure 3. The screen separates oversize and undersize product from on-size product. The oversize product is ground down, typically in a hammer mill, and combined with the undersize material to go back into the process as recycle. Depending on the material, a recycle process may or may not be required to achieve efficient and stable processing. When employed, a recycle circuit can also serve as a buffer in the process, should an upset occur.

PELLETIZING CONSIDERATIONS

There are many aspects to consider in the pelletizing process, but three important considerations stand out as the most influential:

Binder

The binding agent plays a critical role in both the pelletizing process and in the end product quality by influencing pellet formation, green strength and crush strength.

Pellet formation. Binder is used in the pelletizing process to create the tackiness that allows fines to adhere to each other, promoting particle growth. Without this tackiness, pellets and fines would simply tumble with inadequate or non-uniform growth.

Green strength. In addition to aiding in pellet formation, the binder also gives pellets the strength they need to move through the process without breaking down, a property referred to as "green strength" or "wet strength." Pellets require an adequate green strength to withstand the various drop and transfer points encountered during processing.

Crush strength. The binder also impacts end-product crush strength, solidifying the bond between components upon drying. Some binders

may perform well in the pelletizing process, but not produce an adequate crush strength.

The binding agent is a highly customizable part of the process, and often requires testing to determine the best fit. Hundreds of binders are available, and their selection is based on effectiveness, intended product use, cost and availability. The type of binder and the concentration of binder are critical parameters affecting how well the material agglomerates, as well as the amount of dust generated by the pellets upon drying.

Moisture

Controlling the moisture content of the material throughout processing is the foundation of achieving desired product characteristics and ensuring that the process operates smoothly.

All materials have a unique range of moisture within which they will successfully agglomerate (assuming they will agglomerate) via tumble-growth techniques. Some organic materials, like compost, animal feeds and sawdust, have a wide range of acceptable moisture content in which they will agglomerate, while others, like iron oxide, silica dust, many clays and fertilizers, require a very narrow window of moisture content. A delicate balance must be achieved: too much moisture and the material may form clumps or become a slurry; too little moisture and agglomerates will not form properly, or may not form at all.

Since moisture will be added in the form of a liquid binder, the starting material feedstock must fall below the identified range of moisture at which the material will agglomerate. The addition of binder will then bring the material into the ideal moisture range for agglomeration to occur. Consequently, materials containing a moisture content higher than what has been identified as acceptable will require some form of moisture reduction prior to pelletizing.

Preconditioning

Preconditioning is not a requirement in all pelletizing production lines. Some operations simply feed raw feedstock onto the disc pelletizer, omitting the preconditioning step in the pin mixer. However, preconditioning does offer significant value, and may be required depending on the desired end-product characteristics.

The inclusion of a preconditioning step provides several key benefits to the pelletizing process:

Improved product uniformity. While disc pelletizers do promote blending of fines and binder, they are not intended to thoroughly mix the different feed materials. As a result, pelletizing operations not utilizing a preconditioning step may experience an uneven distribution of binder in pellets, resulting in non-uniform product formulation and variable crush strength.

The addition of a preconditioning step ensures that the binder and fines are thoroughly combined into a homogeneous mixture before processing on the disc pelletizer, promoting a highly uniform product.

Increased production. The addi-

tion of a preconditioning step also increases production compared to the use of a pelletizer alone. When using a pelletizer alone, binder and fines are added at a continuous, predetermined rate. Because the addition of binder must be gradual, so as to avoid adding excess moisture to the disc, growing material from fines to the desired-size pellet can take a considerable amount of time. With a preconditioning step, seed pellet formation happens much more quickly, leaving the disc pelletizer with the sole job of increasing pellet size, enabling production rates to increase.

Reduced binder. Part of the intent in pelletizing is to increase product density. When utilizing a pelletizer alone, density is created through the addition of the liquid binder.

Conversely, when a preconditioning step is implemented, density is created not only with the binder, but through the action of the mixer, ultimately reducing the amount of binder required to reach the desired density.

Material influence. Every solid material presents unique challenges when it comes to pelletizing agglomeration. The feed makeup, consistency, moisture content, particle size distribution, and many other factors, will all influence how a material responds to the pelletizing process.

Some solid materials will readily agglomerate, while others simply may not. Some materials will undergo a reaction between constituents that causes pellets to exhibit a higher-than-desired crush strength or other unpredictable attribute. Still others may only agglomerate with significant modifications to the formulation to the product makeup.

Additionally, some materials may require special modifications to the equipment. This is often the case with abrasive materials that could cause excessive wear if not factored into the design process.

For these reasons, testing at batch and continuous scale is often a necessary part of process development for pelletizing lines. ■

Edited by Scott Jenkins

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Improving Bulk-Solids Conveyor Maintenance

Designing easier access to mechanical components in solids-conveying systems reduces maintenance costs and improves safety

Daniel Marshall
Martin Engineering

IN BRIEF

Virtually every vehicle on the road today is designed with an engine hood that can be easily opened for access to the engine, so mechanics can perform routine service and diagnose and address problems that arise during its lifespan. Without that access, cars and trucks would be nearly impossible to maintain, and service life would be short. Bulk-solids conveyor systems should be designed in much the same way, with convenient points along the length of the belt to allow technicians to inspect its condition, perform service as needed and help prevent catastrophic failure.

After nearly a century of working with bulk handlers all over the world, experts have discovered that "maintenance access" is a common element for both safety and productivity across all industries (Figure 1). By adding safe, easy access and monitoring in the design phase, equipment can be better maintained using less labor, leading to reduced downtime. This is reflected in the cost of operation, offering a better overall return on investment.

Unfortunately, this type of access is often overlooked when engineering conveyor systems — until a pressing need arises. The failure to recognize the importance of access on mechanical conveying systems increases the difficulty of ongoing inspection that could have allowed technicians to observe and service critical components before a crisis develops. As a result, lifecycle costs of the conveying system increase while productivity goes down. This is particularly true in a company culture that emphasizes a low-bid process, which encourages bidders to follow a belt-conveyor design methodology based on maximizing the load on the conveyor belt, while meeting the minimum regulatory compliance goals, often using the lowest price materials, components and manufacturing processes available.

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FIGURE 1. Transfer point "access" can mean observation points, entry doors and workspace for service

This article describes best practices and design tips for maintenance access on mechanical conveying systems.

Lifecycle costs

Often when companies make purchasing decisions based primarily on price, the benefits are short-lived, and costs actually increase, resulting in a net loss over time. In contrast, when purchases are made based on lowest longterm cost (lifecycle cost), benefits usually continue to accrue and costs go down, delivering a net savings over the life of the system. In order to win the bid on price, suppliers only have to meet minimum quality and safety requirements, when a little additional investment for safer and more reliable equipment will usually result in an operation that is safer and more sustainable: easier to service, longer life, with lower costs to maintain.

Conveyor technology manufacturers have

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FIGURE 2. Track-mounted components and inspection doors facilitate maintenance for extended equipment life

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FIGURE 3. Track-mounted idlers allow service technicians to quickly swap out failed rollers

responded to the need for increased accessibility to system components by engineering accessories specially designed to reduce labor time while improving safety during service by maintenance staff. Innovative equipment designs, such as slide-out cradle frames, belt cleaner assemblies, idler assemblies — as well as sealed heavy-duty inspection doors — offer better access for safer and more efficient maintenance, resulting in fewer injuries, less labor for service and a lower overall cost of operation.

Conveyor maintenance access

Access doors should be sized as large as the available space will allow, and placed in locations likely to require regular inspection and service. A small access portal may allow inspection, but whenever possible, a larger door will also permit service to be performed, and it should be designed with a minimal ledge on the inside lip, to prevent the buildup of potentially explosive dust. When an access door has a large internal lip, dust can accumulate to depths of an inch or more. By nature, the inside

of a transfer chute is a pressurized area, so when the access door is opened, air movement will carry the dust directly into the face of the person performing an inspection or service, providing an unwanted and unpleasant demonstration of what the bulk material tastes like.

To assist engineers when designing conveyor systems, the seventh edition of the CEMA (Conveyor Equipment Manufacturers Association; Naples, Fla.; www.cemanet.org) handbook Belt Conveyors for Bulk Materials [*1*] provides recommended clearances for servicing components, such as belt cleaners and impact cradles, based on minimum requirements and belt width.

Maintenance access is a cascading issue: improper access leads to poor maintenance practices, resulting in emergency outages and diminishing the operation's productivity and safety. From an ownership and management perspective, downtime and injuries affect profitability through loss of production, capital expenditures for new equipment and ongoing insurance implications.

In the past, managers often decided against the expense of adding safer and easier access points to a conveyor system beyond what is required by code. However, over the system's lifetime, conveyor maintenance professionals estimate that poor access increases maintenance and cleaning costs by 65%.

When designing proper access into a conveyor system, there are three objectives:

- Make components easy to see. If equipment cannot be seen, neither can problems
- Make components easy to reach. Equipment maintenance is likely to be postponed if it is awkward or dangerous to access
- Make components easy to replace. Failing equipment can remain without service for a long period if it is complicated and time-consuming to access

Loading-zone innovations

Across virtually all industries that handle bulk solids, conveyors are increasingly being required to handle higher loads at greater speeds, often rendering original system designs inadequate. Many conveyor transfer points still have an outdated roller system tasked with absorbing impact and centering the material being carried. As a result, components can break and seize, causing friction and creating a potential fire hazard. To replace them, workers must remove the skirtboard and break the plane of the conveyor as they reach across the stringer with heavy tools to assess and repair equipment. Further, traditional skirtboards and wear liners can limit access, with some designs welded to the inside of the chute structure, involving confined space entry with a grinder or blow torch to perform maintenance, repair or replacement. To avoid these complications, specifiers would be well served to consider external wear liners, skirtboards and seals that can be safely serviced from outside the structure, reducing service time and risks.

To reduce maintenance time and labor, improve safety and extend equipment life, operators should

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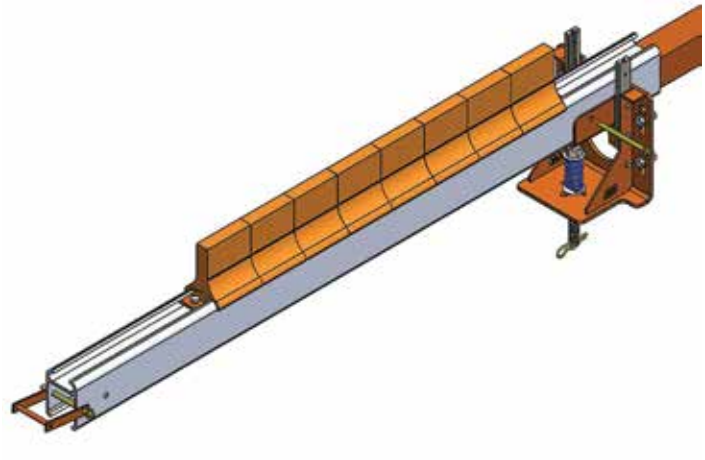

FIGURE 4. Track-mounted components allow fast replacement by a single worker

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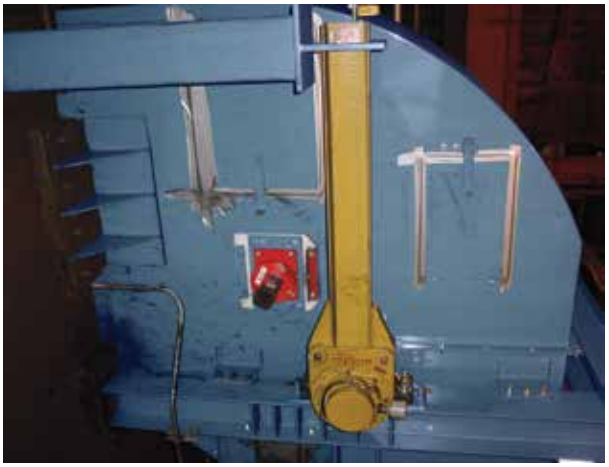

FIGURE 5. Duct tape can have drawbacks when used to seal access doors

consider track-mounted impact cradles and belt support cradles (Figure 2). Located under the skirtboard and mounted with rugged steel assemblies, the cradles feature large impact-absorbing UHMW (ultrahigh molecular weight) polymer "box bars" engineered with smooth surfaces across which the belt can slide with little friction or belt wear. These assemblies can be pulled out by a single worker, working safely from outside the conveyor. In some cases, box bars can be simply removed and flipped over to double the service life.

Along the cargo path in the settling zone and beyond, slide-out/slide-in idlers support the belt and maintain the trough angle. Exposed to the punishing environment, gritty dust and extreme weather, rollers can easily seize. Often set close together in the loading zone to avoid belt sag, easy-to-service roller frames permit workers to perform idler service outside of the belt plane without the need to raise the belt or remove adjacent idlers (Figure 3).

Discharge zone maintenance

Parts that wear, such as belt cleaner blades, need to be monitored, serviced or changed regularly to prevent carryback from causing dust and spillage along the belt path. However, blade maintenance and changes with existing designs can require several hours of downtime.

To address the issue, newly developed automated tensioners have been designed that continuously monitor belt cleaner pressure and wear, automatically adjusting for optimum cleaning performance and service life. An automated tensioner can be run off the existing electrical service or paired with a local power generator, which uses the kinetic energy of the moving belt to generate electricity. Powered auto-tensioners are considered "smart" devices that can deliver realtime performance data from a remote location.

On most existing belt-cleaner designs, primary cleaners — located just under the material flow path on the head pulley — are mounted on rotating assemblies that maintain the proper tension between the blade and the belt. Secondary cleaners are typically located under the belt and behind the head pulley. Both need regular inspection and adjustment to obtain maximum cleaning performance and service life. One way to improve maintenance access and safety while reducing service time is with track-mounted blades that can slide in and out by simply pulling a lever and releasing a pin. This allows maintenance to be performed outside of the system by a single worker — typically in less than one hour (Figure 4).

Inspection doors

A tight seal is the key to preventing fugitive dust from escaping the transfer chute. Many current setups require workers to crouch or crawl under the system or even enter a confined space to inspect the chute or perform maintenance, which can increase the risk of serious injuries. Inspection of the system needs to be fast, easy and safe. Inspection doors — either solid or grated — can allow several observation points. Larger doors can offer access points with ample space for maintenance of specific parts that experience wear.

Real-world examples

The following examples of actual solids-handling operations show the difficulties that can arise with the maintenance of mechanical conveyors, and subsequent solutions to the problems.

Example 1: Dust issues. A west coast coal-handling operation was experiencing dust issues at one of its transfer points, so operators requested an inspection by outside experts. Starting at the top of the transfer zone, technicians initially saw no fugitive material. In fact, they found several access doors that had been cut into the chute by the company's maintenance staff to allow inspection at various points. Then they noticed that the doors were all sealed with duct tape in an apparent attempt to avoid the cost of installing properly-engineered doors with tight-fitting seals (Figure 5).

Duct tape is a versatile tool, but it has some drawbacks when used to seal access points, a fact that was about to become readily apparent. The technicians had to see the material stream to evaluate the dust issue below, and while they were impressed by the ingenuity with which the access points were cut and

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FIGURE 6. Track-mounted components deliver safe, easy access

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FIGURE 7. When the conveyor is running, the dust bags inflate, and a stoppage releases the dust back to the belt

sealed, that tape had to come off. The maintenance supervisor commented that he'd never had to do that, which was an indication that trouble might lie ahead.

The access door provided a good view of the material flow, but the opening allowed huge volumes of dust to billow out, forcing the technicians to quickly re-close the opening. In doing so, they were reminded why duct tape should never be used to seal an inspection door. When it was closed, the door latched properly, but a small gap remained around the edges, which undoubtedly prompted the use of the tape seal in the first place. The air that was now being forced out from that gap travelled at high speed, and carried with it a cloud of airborne dust particles. Unfortunately, the tape that had been removed was no longer sticky and could not be used to reseal the gap. So the technicians were faced with a dense stream of black, flammable coal dust that essentially sand-blasted the team. It took only a few minutes for the supervisor to run downstairs and grab a new roll of

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FIGURE 8. A hatch over the tail pulley allows plant staff to easily detect entrapped material

tape, but they were some of the longest, most unpleasant minutes the men had ever experienced.

By the time he returned and re-sealed the breach, every square inch of the transfer house was covered in a 1/16-in. film of black powder. It looked like every surface had been painted black. To make matters worse, the air in the room was filled with a cloud of dust so thick that it was difficult to see, much less breathe. Coal particles covered ears, noses, hair, safety glasses and clothes, as well as tools and electronics. The group quickly made an exit, but they knew they would be tasting coal dust for days afterward.

Given the physical properties of the dust, the technicians also knew that they had just a day or two before it would begin to self-ignite. The supervisor was so concerned that he didn't even order a cleanup crew to address the problem. Instead, the transfer house was evacuated, and he turned on the fire sprinklers. The entire mess was gone in about ten minutes, avoiding a potential fire or explosion.

A simple cost-saving decision made years ago to save a few dollars resulted in a series of events that could have resulted in a catastrophe.

What could have been done instead? There are well-engineered access doors designed for exactly this scenario, which would have allowed a quick inspection and immediate re-sealing of the opening simply by closing and latching the door. Even this modestly priced solution couldn't compete with a dollar's worth of duct tape, but reviewing the events revealed that the cost savings were an illusion. There were five people on the inspection team, including the supervisor, all of whom lost productive time dealing with the mess. When they realized that the situation had gone beyond any hope of manual cleanup, the transfer house had to cease operation for half an hour while the sprinklers washed down the area, forcing three more workers to evacuate until the dust was gone. That doesn't include the cost of the washdown. That dollar's worth of duct tape turned out to be an expensive "solution" after all.

Example 2: Equipment failures. A coal plant in Eastern China had belt damage, spillage and dust issues at two conveyor transfer points with outdated and inadequate equipment in the loading zones. Raw coal ore was loaded onto the 40 in.- (1,000 mm) wide belts traveling 500 ft/min (2.56 m/s). The first chute had a 16.5-ft (5-m) high drop chute that loaded into a 40-ft (12-m) long loading/stilling zone. The second chute had a similar drop, discharging into an 85-ft (26-m) long loading/stilling zone.

Like many facilities, new demands began to exceed the system's design capabilities, which were originally intended for less tonnage and slower speeds. The belts were supported by impact idlers and a troughed roller system, neither of which were equipped to cope with new production demands. Equipment failures happened regularly, and without proper accessibility for routine maintenance, long periods of downtime were common. Belt sag created gaps between the belt and rollers, causing fugitive dust emissions throughout the facility. Inadequate impact control led to spillage becoming entrapped between the belt and tail pulley, damaging them both. Excessive downtime, costs for cleanup and equipment replacement seriously impacted plant production. Managers sought a solution that better protected the belt, sealed the chute from dust and spillage, and offered easier inspection and ongoing maintenance.

Technicians from an international service provider were invited to perform an on-site assessment and suggest an affordable solution. After offering a detailed proposal, the team installed modern equipment that addressed the issues on both conveyors even though they were of different lengths. The first chute was equipped with a track-mounted impact cradle to improve loading and protect the belt and tail pulley (Figures 6 and 8).

In addition, slider cradles for smoother centering were installed, along with a full-length apron seal to prevent dust and spillage from escaping. A comparable solution was installed in the longer chute, with added cradle support down the entire length. Both chutes featured non-powered dust bag systems to collect emissions (Figure 7).

Since installation, spillage around the loading zones is under control. Dust emissions have been drastically reduced at the facility, measured at less than 3.5 mg/m^3 within the immediate area surrounding the transfer points, and total dust is down to 10 mg/m^3 throughout the facility. Operators report that a considerable drop in equipment failure rates has resulted in a substantial increase in plant productivity. Contributing to the success was workers' ability to easily inspect and service components by sliding them out and servicing them outside of the conveyor. Managers say that workplace safety and the overall work environment have improved significantly. ■

Edited by Scott Jenkins

Reference

1. Conveyor Equipment Manufacturers Association, Belt Conveyors for Bulk Materials, 7th ed., CEMA, 2014, pp. 43–46.

Author

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High-Purity Water Simplified

There are a number of process technologies available to meet the strict standards for high-purity water in different industrial sectors

Jeff Holland, Rich Jarrett and Alan Knapp
Evoqua Water Technologies

IN BRIEF

It is easy to think that the water coming out of our faucets can be used anywhere. Although potable water provided by a municipality is treated and held to specific safety and health standards, it often contains impurities that can have a significant impact on certain manufacturing processes and end products (Figure 1). This article reviews how water is purified for industrial use, why high-purity water is needed in different markets and how to maintain water quality over time.

FIGURE 1. Many industrial processes demand water of higher purity than what is typically provided by municipalities, so additional treatment steps are often required

Purifying water for industrial use

There are a variety of systems and methods available to achieve differing degrees of water purification. Some methods are simple, such as media or carbon filtration, while other systems are far more complex, such as reverse osmosis and ultrafiltration. Typical components of a water purification system include the following:

- Activated carbon — Water is filtered through carbon to remove organic material and chlorine
- Particle filtration — Water is filtered through a physical barrier, removing fine particles and microorganisms
- Reverse osmosis (RO) — Water is forced through a semi-permeable membrane in the opposite direction of the natural flow with enough force to exceed the osmotic pressure, rejecting dissolved solids
- Ion exchange (IX) — Resins remove ionic impurities from water and are regenerated through a reversible chemical process
- Electrodeionization (EDI) — Combines ion exchange and ion-selective membranes with direct current to remove ionic impurities without the need for acids and caustic chemicals
- Ultraviolet (UV) light — Organic carbon reduction, bacteria, viruses and protozoa are exposed to UV light, damaging their DNA and rendering them inactive
- Ultrafiltration (UF) — Membrane filters remove extremely small particles, bacteria and pathogens

Different industries have specific regulations to follow in order to ensure ultrapure water meets their needs. Because each application is unique, a water purification system may include a single technology, or a combination of multiple technologies to achieve optimal results.

Pharmaceuticals and personal care

In the pharmaceutical and personal care markets, high-purity water regulations are defined by the United States Pharmacopeia (USP; Rockville, Md.; www.usp.org) and equivalent organizations in other parts of the world. The USP provides minimum standards around ionic and organic chemical purity and microbial contamination to protect the health and safety of consumers using the

TABLE 1. PROPERTIES OF USP WATER GRADES

Attribute	USP – Purified Water	USP – WFI
Incoming feedwater quality	Meets EPA/WHO drinking water requirements	Purified
Conductivity (µS/cm at 250°C)	<1.3	<1.3
Bacteria (CFU)	<100/1 mL	<10/100 mL
Endotoxin units (EU) per mL	N/A	<0.25
TOC (mg/L)	0.5	0.5

products (Figure 2).

There are two grades of water quality that manufacturers of pharmaceutical and personal-care products may need: USP Purified Water or USP Water-for-Injection (WFI). Both grades have specific minimum levels for certain parameters. These include total organic carbon (TOC) content, as well as the amount of bacteria and endotoxins for WFI. Another important parameter is conductivity, which provides an indication of inorganic materials present in water, and is usually expressed in units of microSiemens (µS) per centimeter. The primary difference between the two grades is the more rigorous set of standards for microbial control required for WFI, as shown in Table 1, and the incoming water quality, for which USP Purified Water is based off of requirements set forth by the U.S. Environmental Protection Agency (EPA; Washington, D.C.; www.epa.gov) and the World Health Organization (WHO; Geneva, Switzerland; www.who.int).

A variety of water-treatment technologies are utilized to achieve these quality standards and typically include a combination of softeners, carbon filtration, UV light, particle filtration, reverse osmosis, ion exchange, electrodeionization and final filtration. In addition, the water treatment system should be regularly sanitized to prevent the growth of bacteria by using chemical, heat or ozone technology.

Medical industry

The healthcare market has very specific high-purity water-quality needs tied to various applications within hospitals, clinical-care facilities and medical research institutions (Figure 3). International and national standards authorities have established water-quality guidelines to ensure the highest-quality care can be provided to patients. High-purity water is critical as a feedwater source to equipment in four key application areas, described in the following sections.

Clinical chemistry and pathology. Reagent-grade water is necessary

FIGURE 2. The production of pharmaceutical and personal-care products requires water that meets specific guidelines set forth by the Unites States Pharmacopeia (USP) organization

FIGURE 3. Water used in healthcare applications, such as laboratory testing and device processing, must meet stringent purity requirements

for laboratory testing and analysis. Poor water quality can affect the efficacy and accuracy of tests, operation of equipment and overall efficiency of the process.

Medical device reprocessing. High-purity feedwater is used for washers, disinfectors and steam sterilizers to clean and sterilize surgical instruments and medical devices. Water quality guidance is provided by the specifications of the Association for the Advancement of Medical Instrumentation (AAMI; www.aami.org) TIR34, "Water for the reprocessing of medical devices" to ensure that medical devices are properly disinfected and safe for patient use. Poor water quality can lead to instrument damage, reduced cleaning efficiency and more.

Dialysis. High-purity water is used as feedwater to dialysis machines and for dialyzer reprocessing and reuse. The incorrect water quality could have an adverse effect on the patient's health and the quality of treatment.

Research laboratories. Several standards and guidelines are followed, such as those set forth by the Clinical and Laboratory Standards Institute (CLSI), ASTM International and the International Organization for Standardization (ISO). Water is one of the major components in many research applications and it is

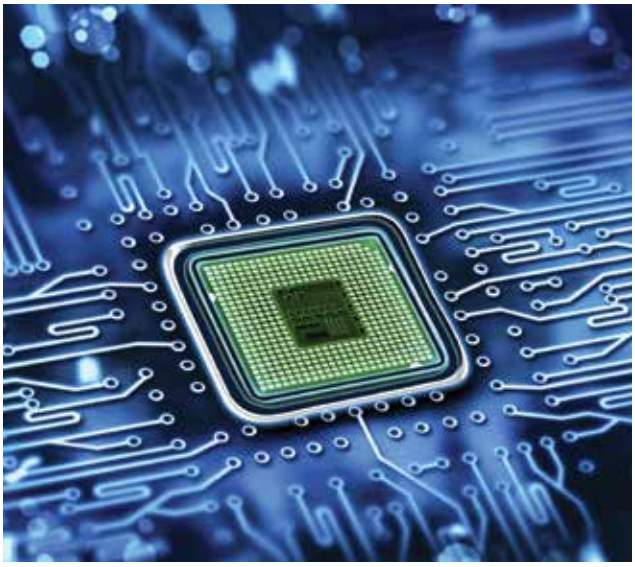

FIGURE 4. For the manufacture of semiconductors, impurities are closely monitored, with emphasis on total organic carbon (TOC), silica, metals and other particles

important to have the correct level of purity for consistent and accurate results.

A variety of treatment technologies are applicable for healthcare and research applications, including softening, carbon pre-treatment, reverse osmosis, deionization, UV and ultrafiltration. It is vital that water quality is consistently monitored to ensure that standards are met and to prevent any risks to research, testing or equipment that could impact patient care.

Microelectronics

High-purity water is used in a variety of applications for microelectronics, from circuits and microchips (Figure 4) to light-emitting diodes (LEDs), photovoltaic (PV) cells for solar panels, silicon wafers and semiconductors. Manufacturing semiconductors is a very complex process involving a myriad of chemicals and specialty gases. In simplistic terms, silicon wafers undergo multiple steps to build the transistors and circuit paths on the wafers. Each step requires high-purity chemicals and gases to create the layers and ultrapure water to rinse. Water-quality standards in these processes typically follow ASTM E-1.1, E-1.2 and SEMI C63 specification requirements with an emphasis on TOC, silica, metals (including boron) and particulate matter.

The ultrapure water (UPW) system is usually made up of three major subsystems to achieve the required water quality: makeup, primary and polish. A typical UPW setup is shown in Figure 5.

Makeup. The makeup system provides pretreatment, which is designed to remove the majority of contaminants from a municipal water supply. Here, greater than 99% removal of anions, metals, silica, TOC and particles is achieved using unit operations of media filtration, carbon filter or chemical feed, advanced oxidation processes (AOP), water softening and reverse osmosis (single or double pass). This equipment typically oper-

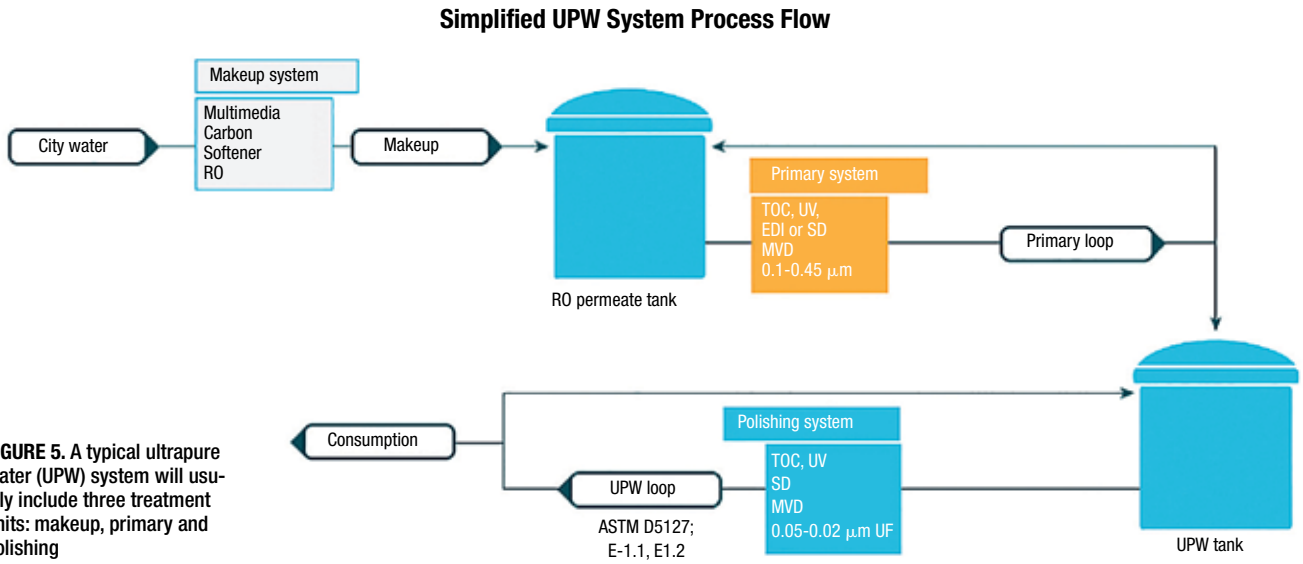

FIGURE 5. A typical ultrapure water (UPW) system will usually include three treatment units: makeup, primary and polishing

ates in an on/off fashion, as it fills a storage tank based on the facilities' water consumption.

Primary. The primary subsystem focuses on the removal of trace amounts of contaminants to lessen the load on the polishing system. TOC-destruct UV, service deionization (SD), membrane vacuum degasification (MVD), EDI or ion exchange and sub-micron cartridge filters (CF) are typical unit operations. This system is designed to run continuously in recirculation and feed the polish loop based on consumption of water in the facility.

Polish. The final part of the treatment system focuses on maintaining the required UPW quality and removing any final traces of contaminants. TOC-destruct UV, polish ion exchange, critical sub-micron CF or UF modules are necessary to meet particle removal needs. This sys-

tem runs continuously at a higher flowrate than the primary system to maintain velocity to the piping distribution loop and laterals that provide water to all factory points of use.

Ramifications of water impurity

Depending on the intended use for high-purity water and the industry, the consequences of water impurity are significant. For the medical, pharmaceutical or personal-care industries, poor water quality can put a patient's health at risk, result in plant shutdowns or cause important drug products to be destroyed. Furthermore, the usage and lifespan of medical equipment and laboratory testing relies on high-purity water. It can impact the longevity of equipment and potentially skew results or disrupt testing practices. Impure water can lead to issues with medical devices and test results in laboratories, which can lead to costly replacements, equipment downtime or delays in care.

Manufacturing and microtechnology rely on ultrapure water to make sure the smallest pieces of electronics and technology run as they should. Issues with impure water can cause disruptions in manufacturing, costing the manufacturer time and resources to solve the problem. Furthermore, it exposes the manufacturer to possible widespread product defects and recalls, depleting resources even further.

Servicing a UPW system

Proactively avoiding issues with a water purification system is just as important as selecting and installing the system in the first place. A well-planned and maintained system is extremely important to protect both the manufacturer and the end user.

Ultimately, the manufacturer is responsible for establishing the specific water-quality standards that it needs to build into its process to ensure the water being used meets industry and safety guidelines. As a result, manufacturers often look to water-treatment technology providers to understand water standards and assist with system design, installation and ongoing service to maintain water quality and reliability.

Since a water-purification system is as complicated as it is important, requiring a sophisticated knowledge base encompassing mechanics, physics and chemistry, partnering with an expert can prove to be very valuable. To ensure that high-purity water flows without any problems, a service provider should offer an understanding on meeting water-purity industry standards, know-how to design and build an appropriate water-treatment system and have the capability to provide timely and reliable maintenance and repairs. ■

Edited by Mary Page Bailey

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Rich Jarrett is the pharmaceutical market director at Evoqua Water Technologies (Email: richard.jarrett@evoqua.com). In this role, Jarrett leads efforts related to water-treatment solutions and product requirements for the pharmaceutical industry. He has more than 14 years of experience working with the pharmaceutical industry in developing products and services for improved quality, reduced cycle time, enhanced manufacturing and regulatory compliance. He earned a B.S. degree from Cornell University and an M.S. in business administration from the Kellogg Graduate School at Northwestern University.

Alan Knapp is the microelectronics market director for Evoqua Water Technologies (Email: alan.knapp@evoqua.com) and is responsible for identifying industrial ultrapure/wastewater challenges and developing solutions for customers in the semiconductor, nanotechnology and solar energy markets. He has been active with ultrapure water and wastewater solutions in the industrial market since 1984. Knapp has a mechanical engineering technologist diploma from Conestoga College in Kitchener, Ontario, Canada, along with several accreditations with ASME and ISO. He is also an active member of the International Roadmap for Devices and Systems (IRDS) committees and a member of the SEMI organization and a co-moderator at the GWI Ultrapure Micro Conference. He has published several papers for *Ultrapure Water Magazine* and the International Water Conference.

IFAT (rescheduled for September 7–11, Munich, Germany; www.ifat.de) is the world's leading tradefair for water, sewage, waste- and raw-materials management. More than 3,000 exhibitors are expected to participate, presenting the latest products and services spanning the environmental sector, from sewage-treatment plants to the use of comminution machines in refuse treatment. The innovations presented at IFAT aim to promote the sustainable use of the available resources in order to protect and improve our quality of life and the state of the environment.

A sample of some of the new products being exhibited at IFAT 2020 is presented below. More can be found at www.chemengonline.com.

Auma Riester

This smart actuator is 'as cunning as a fox'

Aimed at process and water applications requiring fast and precise positioning, flexibility and future-proof interfaces, Profox actuators (photo) combine high performance with new features and an "excellent" cost-benefit ratio, says the company. Built-in intelligence makes Profox equally suited for open-close duty and modulating applications. Adjustable speed ensures fast and precise positioning. Operating costs are low, thanks to high mechanical efficiency and low standby consumption. Profox actuators work with gate, butterfly, ball and globe valves. There are multi-turn versions for torques of 10–100 Nm and partial-turn versions delivering 32 to 600 Nm. A linear actuator will follow soon. The most common communication protocols are supported. IP67 protection (IP68 optional) and the company's unique corrosion protection ensure that Profox actuators have a long life, even under the toughest process conditions at temperatures from –30 to 70°C. Hall C2, Stand 141/240 — *Auma Riester GmbH & Co. KG, Müllheim, Germany*
www.profox.auma.com

Gebr. Lödige Maschinenbau

A versatile mixer for chemical and thermal processing

The continuous Ploughshare mixers of the KM series (photo) are particularly suitable for environmental engineering applications. This low-maintenance mixer model is intended for processing powders, fibrous or granular solids, as well as fluids and pastes. The continuous mixer even performs granulating processes with minimum retention times. It is characterized by excellent repeatability, maximum homogeneity of the final product, short retention times and great economic efficiency. Beyond processing of dry, powdered, granular or fibrous solids, it can also be equipped for numerous other mixing tasks. The smallest model (with a drum volume of 5 L) has a feedrate of 0.25 m^3/h based on retention time and degree of filling. The feedrate of the largest model to date (57,000-L drum volume) is 1,300 ton/h. Hall A4, Stand 441 — *Gebr. Lödige Maschinenbau GmbH, Paderborn, Germany*
www.loedige.de

Flottweg

High-performance, large-scale machine for sludge treatment

The lower the sludge volume, the lower the cost of transportation and disposal. High performance in sludge dewatering is therefore the decisive criterion for reducing operating costs. Since its launch in 2018, the Xelletor series has achieved impressive results in terms of throughput, polymer consumption and energy requirements. In comparison to other modern machines, it offers up to 15% more throughput, up to 2% higher dry-solids content and up to 20% savings in flocculant and energy consumption, says the manufacturer. The company now complements its product portfolio with the top-of-the range X7E (photo), which is being launched at IFAT. This newest Xelletor development has a capacity of up to 130 m^3/h and is therefore suitable for medium to large sewage treatment plants. At IFAT, the company will also will demonstrate what automation can offer operators of municipal sewage-treatment plants. The company provides a comprehensive package for the full automation of sewage-sludge dewatering and thickening. Hall A1, Stand 550 — *Flottweg SE, Vilsbiburg, Germany*
www.flottweg.com ■

Gerald Ondrey

INTERPHEX

Stäubli North America

VEGA Americas

L.B. Bohle Maschinen + Verfahren

ViscoTec America

Interphex 2020, originally scheduled for April 28–30, has been postponed to July 15–17. Taking place at the Javits Center in New York City, the biopharmaceuticals-focused event offers a full technical conference with dedicated session tracks covering compliance, inspection, automation and much more; and an exhibit hall featuring over 600 exhibitors, many of whom are debuting new equipment and technologies. For 2020, Interphex is co-locating with Chemspec USA, a new event focused on fine, specialty and custom chemicals for use in several market verticals, including pharmaceuticals, biologics, agrochemicals and biocatalysts. After its debut in 2019, Interphex will bring back the Innophex space within its show floor. Innophex will highlight disruptive technologies, including gene therapy, cell processing and more. Furthermore, a new Exhibitor Spotlight Zone will welcome Interphex's newest exhibitors with special highlights. This Show Preview covers a small selection of the products and services that will be on display at Interphex 2020.

Use these robots in processes with stringent decontamination

The Stericlean range of fully encapsulated robots (photo) are compatible with decontamination processes using vaporized and liquid hydrogen peroxide, at concentrations up to 35% H_2O_2. Designed with cleanroom operation in mind, the robots feature special seals and surface treatments, as well as a proprietary food-grade lubrication oil to safely lubricate each axis. Theses axes are put in motion by this company's proprietary JCS drive technology on all models, which facilitates high-speed motion and high repeatability for ultra-short cycle times. The special seals and surface treatment, combined with the ability to pass all connections through the base and inside the arm, enable for shorter decontamination cycles in controlled or aseptic environments, as well as laboratory integration of all four- and six-axis Stericlean models. Booth 2159 — *Stäubli North America, Duncan, S.C.*
www.staubli.com

These sensors feature a standardized adapter system

This company has recently launched its line of VegaBar pressure sensors and VegaPoint point-level switches. The compact instrument series is tailored for applications requiring high levels of quality control and strict hygiene. The standardized, hygienic adapter system and process fittings (photo) provide the flexibility needed to keep installation efforts and parts inventory to a minimum. Also, sensor setup is simplified with secure Bluetooth connectivity. All VegaBar and VegaPoint sensors can be configured using a smartphone or tablet. The new sensors also feature universal communication. Standard IO-Link protocol offers intelligent data transfer and simple integration into any system. Booth 3847 — *VEGA Americas, Inc., Cincinnati, Ohio*
www.vega.com

Advanced dry-granulation system for reliable containment

The BRC Series of dry granulators now includes the new BRC 100 Containment model (photo). Along with a standard mechanical drive, which eliminates the need for hydraulics, this new model is equipped with fast controls that enable fully automated operation. The unit includes a glovebox with security prompts and dedicated containment ports for sample collection, as well as containment ports underneath the sieve unit for the removal of granules. An integrated insulator unit features corresponding vacuum monitoring, and also provides convenient access, since there is no complete insulator installed around the entire compactor. Booth 2954 — *L.B. Bohle Maschinen + Verfahren GmbH, Ennigerloh, Germany*
www.lbbohle.com

Hygienic dosing for two-component systems

The new ViscoDUO-VM HD dosing system (photo) is designed to process two-component fluids and pastes in hygienic processes. The new dosing system offers continuous mixing and dosing of two low- to high-viscosity materials with the same or different viscosities and guarantees precise,

repeatable and process-safe mixing in a validated process. The modular design of the ViscoDUO-VM HD features four different sizes on both sides, which allows it to be used in a wide range of applications. Flowrates from 0.5 to greater than 1,000 mL/min can be implemented. Thanks to the built-in endless piston principle, dosing is completely pulsation-free. All components in contact with the product are made of stainless steel, and can be issued with a batch certificate if required. Booth 3742 — *ViscoTec America, Inc., Kennesaw, Ga.*
www.viscotec-america.com

This connection system offers full containment during docking

The SafeDock system (photo) enables full product containment in toxic or sterile processes while making docking operations faster and simpler. The fully sealed, pressure-tight system consists of a single dead-zone-free docking tube with an automated cover to close the system. A side port featuring a continuous liner system is used for the removal of the inliner. The bag spout is sealed by a flexible single-use ring, which can be easily removed with the remaining liner in a closed manner through the side port. This high safety system guarantees optimal sealing at all times without external energy sources. Clean-in-place (CIP) tasks are made more efficient with the optional CIP cover. The system is solvent-resistant, and various coatings options are available. *Booth 3161 — Dec Group, Ecublens, Switzerland*
www.dec-group.net

Streamline the loading and unloading of freeze-drying units

The patent-pending LyoShuttle system (photo) offers automated loading and unloading of freeze dryers in a robust unit. Cleaning and disinfection of the complete system are simplified because the system has very few moving parts. The freeze dryer employs a loading robot that uses timing belts to move horizontally on a set of rails mounted at a constant loading level. Thanks to its flexible and space-saving construction, the LyoShuttle is suitable for production freeze dryers in pharmaceutical manufacturing, including those under insulated conditions. The LyoShuttle system is also designed for integration into an isolator environment. Booth 3711 — *Martin Christ Gefriertrocknungsanlagen GmbH, Osterode, Germany*
www.martinchrist.de

A semi-automatic inspection machine for liquid or dry products

The CMP PHAR.MA SV (photo) is a semi-automatic machine for the inspection of liquid, lyophilized or powder products in ampoules, vials and cartridges or pre-filled syringes. The containers are automatically conveyed from the machine to the inspection station, where the operator, looking at the containers, decides whether to accept or reject them. It is equipped with brushless motors for fast rotation (before inspection) and slow rotation (during inspection) to guarantee complete and efficient product control. The machine can handle up to 100 pieces per minute, with a range of diameters from 8 to 78 mm. The machine is designed to comply with current GMP regulations, and its software is in compliance with 21 CFR Part 11. Booth 3125 — *Marchesini Group, West Caldwell, N.J.*
www.marchesini.com

New servo motors expand these pumps' operating range

This company now offers servo motor technology for its eVmp precision metering and dispensing pump (photo). The integration of this technology allows the pump to attain higher production speeds and manage fluids with much higher viscosity than was previously possible. The patented eVmP pump combines precision ceramic-pump components and an electronically controlled linear stepper actuator to make ultra-fine adjustments to angle position, thereby changing the volume of metered liquid. This allows the eVmP pump to provide dynamic fluid displacement to overcome variations in viscosity and surface tension. With nearly four times the torque of a traditional stepper motor, the eVmP servo drive can handle flowrates near 2,000 mL/min. Booth 1957 — *Zaxis, Inc., Salt Lake City, Utah*
www.zaxisinc.com ■

Mary Page Bailey

Dec Group

Martin Christ Gefriertrocknungsanlagen

Marchesini Group

Zaxis

INTERNATIONAL
POWDER & BULK SOLIDS
CONFERENCE & EXHIBITION


Paul O. Abbe


Dynamic Air


Posi-Flate


Material Transfer & Storage

The biennial International Powder & Bulk Solids (iPBS) Conference & Exhibition will be held October 6–8 (rescheduled from April 28–30) at the Donald E. Stephens Convention Center in Rosemont, Ill. The event features an expo hall with over 425 exhibitors and a conference session offering a variety of technical sessions, as well as hands-on demonstrations showcasing pneumatic conveying, storage and feeding best practices. The technical conference includes four dedicated session tracks: Material Flow and Storage; Bulk Solids Conveying; Dust Collection and Safety; and Solids Processing and Quality. This Show Preview highlights a small selection of iPBS exhibitors.

Sanitary ribbon blenders with many built-in features

This company offers a sanitary ribbon blender with a stainless-steel, washdown, servo-actuated cover lift (photo). The blender includes a bomb-bay valve or a patent-pending sanitary-orifice gate valve with no dead area. The blender is constructed fully of stainless steel, which is polished on the inside and glass-bead blasted on the outside. Other features of the blender include a low-maintenance, hollow-bore drive, an optional spray bar, dimpled heating jacket and NEMA-4X protected stainless-steel controls. Sizes ranging from 10 to 400 ft^3 are available. Booth 2321 — *Paul O. Abbe, Wood Dale, Illinois*
www.pauloabbe.com

Tailor-made pneumatic-conveying systems

This company's custom-designed pneumatic-conveying systems provide options for 16 different pneumatic-conveying concepts to handle a wide variety of dry bulk solids. A fully operating dense-phase pneumatic-conveying system (photo) will be showcased at iPBS. Each system is custom-designed to achieve optimum performance characteristics at high efficiencies. In addition to pneumatic conveying, the company provides mixers, bag-handling systems and vibratory equipment. Booth 1307 — *Dynamic Air Inc., St. Paul, Minn.*
www.dynamicair.com

Use these butterfly valves in severe-service applications

Series 585 and 586 inflatable seated butterfly valves (photo) are designed for the most severe of applications. The new heavy-duty seat has been designed for high operating pressures and temperatures. Standard valve sizes range from 2 to 24 in. (50 to 600 mm) and fit both ANSI and metric flanges. A full line of actuators, limit switches and controls are available to suit individual applications. Housing material options include: cast iron, stainless steel, aluminum, nickel-plated cast iron, epoxy-coated cast iron and nylon-coated cast iron. As the valve rotates into the closed position, the disc makes only casual contact with the seat, reducing friction, wear and torque requirements. After the valve is closed, the seat inflates against the disc, providing more sealing surface and an even pressure distribution against the disc. Before the valve opens, the seat is first deflated. The disc is then free to rotate to the open position. Booth 1008 — *Posi-Flate, St. Paul, Minn.*
www.posiflate.com

Use this conditioner system for smoother material transfer

The new Material Master bulk-bag conditioner (photo) is a hydraulic system featuring a rotary-lift platform, which quickly and safely returns solidified materials in bulk bags to a free-flowing state. The operator loads the bulk bag into the unit via forklift and activates a PLC-controlled conditioning sequence. Twin pivoting conditioning arms with extended travel penetrate deeply into the material for effective results. The rotary-lift platform positions the bulk bag during the conditioning sequence, ensuring the bag is thoroughly conditioned from top to bottom. A patented design returns even severely agglomerated materials to a free-flowing state. The operator interface allows control of all conditioning parameters, including recipe management, system status and manual mode controls. Units are custom designed for application requirements. Booth 3317 — *Material Transfer & Storage, Inc., Allegan, Mich.*
www.materialtransfer.com

Self-aligning pipe and tube couplings


Tuf-Lok

This company offers heavy-duty self-aligning couplings (photo) for either high-pressure (up to 150 psig) or full-vacuum-rated applications. Utilized wherever pipe and tube ends need to be connected, these couplings are suitable for pneumatic conveying systems, as well as for gas and liquid applications. The couplings are available in pipe sizes ranging from 2 to 10 in. and are made for use on plain-end pipe or tube, regardless of wall thickness. The couplings are self-grounding, vibration-resistant and externally leak-proof. No machining or grooving is required to maintain pipe or tube integrity. Various gasket materials are available for high temperatures or chemical-resistant applications. Booth 1006 — *Tuf-Lok International, Madison, Wis.*

www.tuflok.com

Improved ergonomics and ingredient handling


Vac-U-Max

ColumnLift vacuum-receiver systems (photo) provide access to mixers or other process vessels that have opening and closing hatches. Users will find improved ergonomics due to reduced lifting and stair climbing, greatly reducing the risk of injury. The ColumnLift system also improves sanitation practices, since equipment can be serviced from ground level instead of working at an elevation. Also, the system reduces the ingredient-handling stage of the process by allowing cleaning and sanitation to occur during the mixing process. The ColumnLift system works with all types of bulk powder containers, including paper bags, drums, intermediate bulk containers, bulk bags or silos. Booth 1219 — *Vac-U-Max, Belleville, N.J.*

www.vac-u-max.com

Blend and convey multiple materials in a single unit


Cyclonaire

The CB Series Blend-Veyor (photo) is designed to blend and convey powdered, friable materials from multiple sources. Users can blend and convey two or more materials in one unit, resulting in greater efficiency and less product degradation. The units feature vacuum-loaded, semi-dense-phase blending and conveyance with capacity up to 800 ton/h. Blend-Veyors use a single 15-psi positive-displacement blower for vacuum-pressure conveying at low line velocities (<2,000–5,000 ft/min) and high material-to-air ratios, reducing material degradation and abrasive line wear. Besides blending, the unit is capable of bulk carrier unloading and in-plant transfer, as well as weighing and batching with inventory control. Booth 3427 — *Cyclonaire Corp., York, Neb.*

www.cyclonaire.com

Mary Page Bailey

Detection Systems for Reducing the Risk of Hydrogen Fires

Today's detection equipment can provide early sensing of H_2 gas and flames, provide alarm information to a fire- and gas-safety system controller to initiate mitigating measures, and integrate with process control to further minimize H_2 fire risk

Michael J. Hosch and Aaron Paterson
Det-Tronics

Hydrogen is the most flammable element on earth [*1*]. However, this colorless, odorless and tasteless substance rarely exists in its pure form. Instead, it normally combines with other elements, in water molecules, for example, or in industrial compounds. However, H_2 is widely used in the chemical process industries (CPI, Figure 1). For example, in the chemical industry, it is an important component in the production of polymers and ammonia for fertilizers. In petroleum refining, it is used in the reforming process for producing high-grade gasoline, as well as in removing sulfur compounds from petroleum so they will not poison vehicle catalytic converters [*2*].

According to the U.S. Dept. of Energy's Office of Energy Efficiency & Renewable Energy (www.energy.gov/eere), 10 million metric tons of H_2 are produced in the U.S. annually [*3*]. While playing an indispensable role in many processes, H_2 also poses a unique and potentially significant threat to chemical processing facilities. The dangers to personnel and property, however, can be minimized by choosing the right equipment to detect and respond to hydrogen-related hazards.

Challenges with H_2

The challenge with using H_2 in CPI plants and other industrial settings is that this nontoxic and seemingly harmless gas has highly reactive and explosive properties. In fact, the National Fire Protection Association (NFPA; Quincy, Mass.; www.nfpa.org) — the main fire codes and standards organization in the U.S. — gives H_2 its highest rating of "4" on the flammability scale (Figure 2), because H_2 is flammable when mixed with other elements, even in small amounts with ordinary air [*4*].

FIGURE 1. Hydrogen is widely used throughout the chemical process industries

In addition, it only takes a small amount of energy to ignite H_2. The gas can even self-ignite without energy from an external source when it is leaking from a pipe at high pressure.

Making matters more challenging for plant personnel and unlike a hydrocarbon flame, a H_2 flame cannot be easily detected by human senses (Figure 3). Workers approaching a H_2 flame may not see it, even up close. Instead, they may see a shimmering, mirage-like area or possibly sparks, which are actually dust particles burning briefly in the flame.

Adding to the danger, personnel approaching a H_2 flame will not feel intense heat. This is because H_2 flames typically emit less of the infrared (IR) radiation that causes humans to sense heat when near a flame than hydrocarbon fires.

With little or nothing to see and a small amount of radiant heat to be felt, human senses may not warn people to stop as they approach a H_2 flame, potentially allowing them to unknowingly walk right into it.

First line of defense

For the reasons just mentioned, chemical plants that use H_2 need fire and gas (F&G) safety systems with flame and gas-leak detection technologies in order to minimize fire-related risks to personnel and processes. The first line of defense against H_2-related dangers is gas detection equipment. Though people cannot see, smell or taste H_2 gas under normal conditions, gas detection equipment can sense a leak before it ignites, increasing the possibility of stopping a leak before it causes

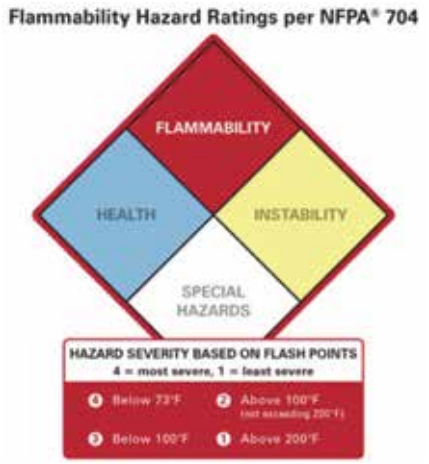

FIGURE 2. Materials rated a "4" in terms of flammability in NFPA 704 are those that will readily burn at room temperature, including acetylene, propane and hydrogen gas

FIGURE 3. Every combustible gas burns differently, producing a signature flame. Compared to hydrocarbon flames, depicted on the right and left, a hydrogen flame (center) emits little visible light and infrared radiant heat, and is therefore more difficult to detect

a fire or explosion.

Two common technologies for detecting combustible gases are IR and catalytic bead (Pellistor) detectors. Today's IR-based combustible-gas detectors cannot detect H_2. This makes catalytic bead-type detectors the appropriate technology choice between the two for detecting H_2 in combustible concentrations.

A catalytic bead sensor detects a combustible gas that combines with oxygen to produce heat. This sensor usually consists of a matched pair of platinum wire-wound resistors, one of which is encased in a ceramic bead. The active catalytic bead is coated with a catalyst, while the reference catalytic bead remains untreated. The resistors are then enclosed behind a flame-proof sinter or porous filter.

When a combustible gas comes in contact with the active catalytic bead surface, the gas is oxidized and heat is released, which changes the resistance of the wire. The reference (or passive) bead maintains the same electrical resistance in clean air as the active bead, but does not catalyze combustible gas. Combustible gas concentrations are then determined by comparing the difference between the active and passive bead circuits.

On the downside, catalytic bead detectors may not have the ability to signal a fault when they fail. They are also susceptible to poisoning, which can cause them to fail when exposed to silicones and other common chemicals in industrial environments. In these cases, the porous filter clogs, causing the active bead to behave in the same manner as the reference bead. If the active bead in a catalytic detector cannot sense gas, plant personnel have no way of knowing. Therefore, periodic bump or proof testing with calibration gas is required to ensure proper sensor operation.

Plant personnel or others placing catalytic bead-type gas detectors should keep in mind that light H_2 gas quickly floats upward and disperses. Therefore, detectors should be located close to and above spots where a leak might occur — just above a valve, for example.

Flame detection options

If a H_2 leak does ignite, F&G safety systems include detectors that can quickly sense a H_2 flame. One option for H_2-flame detection is a thermal heat detector, which will not sound an alarm until the temperature of the monitored area exceeds the detector's alarm set point. For best results, these detectors should be placed directly above the sites of a potential H_2 flame.

Even in this position, the source of a H_2 leak may produce a flame directed away from the detector, delaying the response time. Another concern for users of thermal detectors is that a H_2 flame's low IR radiation may not be enough to trigger an alarm.

An alternative to thermal detection is an optical detector that can "see" a hydrogen flame. Compared to hydrocarbon flames, however, hydrogen flames emit little visible light or IR radiant heat. One potential option is to use an optical detector that senses the ultraviolet (UV) radiation emitted by hydrogen flames.

UV flame detectors use anode/cathode Geiger-Mueller-type vacuum tubes to sense UV radiation. When this radiation enters the vacuum tube and strikes the cathode, energy from the UV photon releases a photoelectron and creates an electrical impulse as it travels to the anode. UV flame detectors excel at fast detection of H_2 flames.

On the other hand, UV flame detectors are sensitive to arcs, sparks, welding, lightning and other UV emitting non-flame sources. These sources can cause the detectors to alarm, which may result in costly production downtime.

Therefore, UV flame detectors are best suited for enclosed rooms and other locations isolated from potential sources of false alarms. Even in enclosed rooms, it may not be possible to eliminate all sources of nuisance alarms from UV sources.

Superior false-alarm rejection is one of the main reasons multi-spectrum infrared (MIR) flame detection has become the preferred choice of many operators for detecting H_2 flames in most industrial settings (Figure 4). With a unique set of IR sensor filters, some MIR detectors are designed specifically to detect the IR radiation from H_2 flames.

MIR flame detectors rely on a combination of IR filters and software analysis to detect flames and reduce the potential for false alarms. Unlike UV flame detectors, MIR detectors are designed not to enter an alarm condition when exposed to arcs, sparks, welding and lightning.

In H_2-detection applications, MIR detectors offer good response time and range. Equipped with an opti-

Det-Tronics

FIGURE 4. To "see" hydrogen flames, today's best technology is multispectrum infrared flame detection, as used in this hydrogen flame detector

mum IR filter set, some MIR devices can detect H_2 fires at about double the range of a UV flame detector. While the range of MIR detectors can be reduced by the presence of water or ice on the lens, some detectors are equipped with lens heaters that melt ice and accelerate evaporation of water.

Brain of the system

To continuously monitor and analyze data from gas and flame detectors, F&G safety systems require controllers that provide alarm monitoring and some level of diagnostics. If a hazard is detected, the controller takes the appropriate actions based upon its pre-programmed logic. These actions often include providing alarm notification and activation of suppression systems to mitigate the hazard. In addition to handling inputs and outputs, the controller should be able to provide realtime F&G safety system status and diagnostics. It should also facilitate programming and configuration of flame and gas detectors, as well as other field devices that are part of the F&G system.

Typically, F&G safety-system controllers have been limited to being hardwired together using analog or contact closures in a conventional (that is, point-to-point) design. Though capable of providing alarm and fault information, the conventional design does not give controllers access to specific details of fire-related events because of the simple, binary nature of the communication path. In addition, this design provides only limited diagnostics, is not inherently fault-tolerant and limits configuration flexibility.

This is why today's advanced F&G safety systems feature a redundant control and bi-directional fault-tolerant loop design. Systems of this type are safety integrity level (SIL)-2 certified and provide alarm, fault, status and enhanced diagnostic information that can be communicated with other subsystems, such as process control. The controller is in constant communication with each device in the loop, so it has the latest alarm and diagnostic information, making this configuration more reliable than point-to-point designs as well.

Control system integration

Consider a situation in which flammable materials continue to be pumped into an area of a chemical plant where fire has been detected. To prevent potentially disastrous scenarios like this, it is imperative that the plant's F&G safety system be able to communicate with the process control system (PCS).

Any F&G system deployed in a chemical facility should be able to provide detection-device status in defined process areas to the PCS so the process owner is kept informed about events that may threaten personnel and/or operations. While this level of integration is important, the F&G system must remain independent of the PCS, so failure of the PCS will not affect vital fire-protection functions in the facility.

Performance of both of the F&G system and the PCS must be validated to ensure they are capable of reaching the defined risk-reduction target for the facility. Applicable performance requirements are contained in codes and standards. Performance information about specific equipment is provided in manufacturer documentation.

Product certification

F&G systems and equipment are covered in fire standards such as NFPA 70 (the NFPA 70 National Electrical Code) [*5*] and NFPA 72, the National Fire Alarm and Signaling Code [*6*] The surest way to know that fire-protection equipment meets safety standards, such as those in NFPA 70 and 72, is to specify equipment with certification documentation. Performance testing and certification verify that a device will operate as specified by the manufacturer under a wide range of conditions. F&G safety systems and key components, such as controllers and detectors, should be properly certified for hazardous locations, performance and functional safety.

Product testing and evaluation should be conducted pursuant to the requirements of a properly accredited third-party testing and certification agency, which provides potential users with an independent and unbiased product evaluation. A number of highly regarded independent organizations test fire-protection equipment using their own documented safety and performance criteria. Manufacturers using this evaluation approach will be able to provide proof of certification for their products. ■

Edited by Gerald Ondrey

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Authors

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Aaron Paterson is the Flame Product Line manager at Det-Tronics (same address as Hosch, above; Phone: 952-946-6471, Email: aaron.paterson@det-tronics.com). Paterson has been providing technical support to Det-Tronics customers who use flame and gas detection in challenging and unique environments since 2012. In his current role as Flame Product Line manager, Paterson is responsible for recommending product innovations and developing product roadmaps for the flame detection product line. Paterson has a bachelor's degree in business administration from North Dakota State University.

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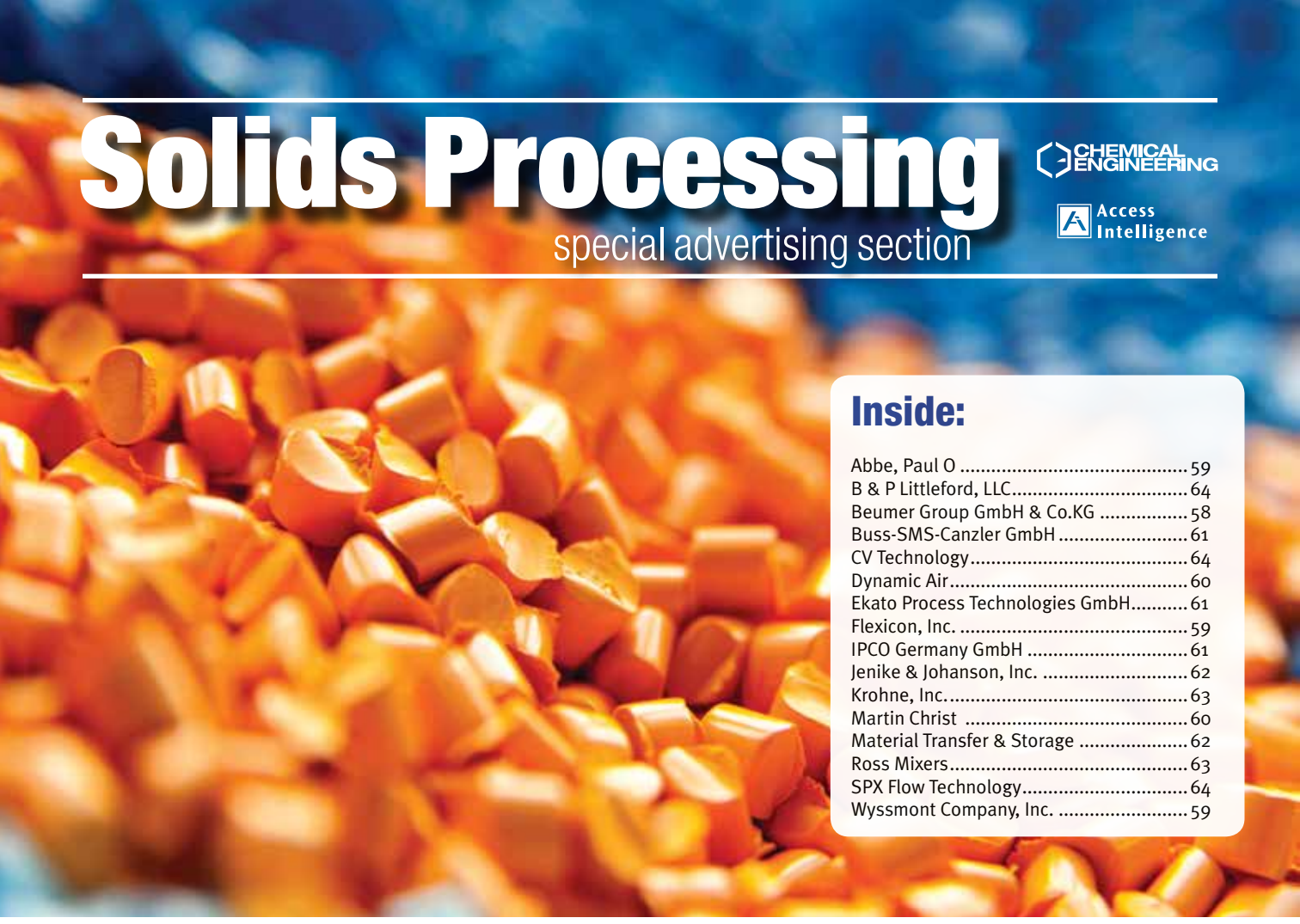


Inside:

BEUMER Group presents itself as single-source provider for packaging lines that work perfectly together

The chemistry is right

BEUMER Group develops complete packaging lines from one source for (petro) chemical companies. This means that the customer can omit or minimise interfaces and only needs one point of contact. What is special is that the system supplier dimensions the performance of the single machines and components as well as the high-level control in an optimum way. Thus the customer receives a complete line with optimum throughput.

The form-fill-seal system BEUMER fillpac FFS forms a ready-made tubular PE film into a bag and fills it with the customer's product like PE, PP, PA or PS pellets. The pellets are then weighed before the filling process. For this, the BEUMER fillpac FFS is equipped with an electronic calibration-capable weighing unit. Then the system seals the bags with a weight of up to 25 kg. BEUMER Group offers the BEUMER fillpac FFS both for the high-capacity area of up to 2,600 bags per hour and for low throughputs up to 1,800 or 2,500 bags per hour. Depending on the customer requirements the suitable machine performance class can be selected from the extended product range.

After filling, the bags are stacked on pallets in stable and precise way. The BEUMER paletpac of the system supplier is perfectly suited to this. It is easily accessible for maintenance, can be operated intuitively and flexibly adapted to different packing patterns. For palletising bags, barrels, canisters, cartons or buckets, BEUMER Group offers the BEUMER robotpac. The user receives gripping systems suitable for all types of packaged goods, which can be easily exchanged.

The high-capacity stretch film packaging system BEUMER stretch hood covers the palletised goods with a high-stretchable stretch hood film. During transshipment and outside storage, the merchandise is protected reliably against environmental influences such as sunlight, dirt and humidity.

BEUMER Group is an international leader in the manufacture of intralogistics systems for conveying, loading, palletising, packaging, sortation, and distribution. With 4,500 employees worldwide, BEUMER Group has annual sales of about EUR 950 million. BEUMER Group and its group companies and sales agencies provide their customers with high-quality system solutions and an extensive customer support network around the globe and across a wide range of industries, including bulk materials and piece goods, food/non-food, construction, mail order, post, and airport baggage handling. For more information, please visit:

www.beumer.com

The easy, intuitive and reliable operation of the new BEUMER stretch hood A is especially appealing to customers. Picture credits: BEUMER Group GmbH & Co. KG

Handle virtually any bulk solid material

Flexicon stand-alone equipment and automated plant-wide systems convey, discharge, condition, fill, dump and weigh batch bulk materials dust-free

Flexicon engineers and manufactures a broad range of equipment that handles virtually any bulk material, from large pellets to sub-micron powders, including free-flowing and non-free-flowing products that pack, cake, plug, smear, fluidize, or separate.

Individual bulk handling equipment includes: flexible screw conveyors, tubular cable conveyors, pneumatic conveying systems, bulk bag dischargers, bulk bag conditioners, bulk bag fillers, bag dump stations, drum/box/container dumpers, and weigh batching/blending systems. Each of these product groups encompasses a broad range of models that can be custom engineered for specialized applications, and integrated with new or existing upstream and downstream processes and storage vessels.

All equipment is available to food, dairy, pharmaceutical and industrial standards.

For large-scale bulk handling projects, Flexicon's separate Project Engineering Division provides dedicated Project Managers and engineering teams on four continents to handle projects from concept to completion. Working with each customer's preferred engineering firm or directly with their in-house team, Flexicon adheres strictly to the customer's unique standards, documentation requirements and timelines through a single point of contact, eliminating the risk of coordinating multiple suppliers.

Flexicon's worldwide testing facilities simulate full-size customer equipment and systems, verify performance prior to fabrication, demonstrate newly constructed equipment for visiting customers, and study the performance of new designs.

Flexicon offers stand-alone bulk handling equipment as well as plant-wide systems integrated with new or existing processes

The company recently doubled the size of its manufacturing facility and world headquarters in Bethlehem, PA, and also operates manufacturing facilities in Kent, United Kingdom; QLD, Australia; and Port Elizabeth, South Africa.

www.flexicon.com

Rota-Cone® Blender

The **Paul O. Abbe** Rota-Cone® blender is the ideal choice for thorough and gentle blending of powders or crystalline products. Because this tumble blender has no shaft seals or agitator, cleaning is simplified and cross-contamination minimized. All internal surfaces the Rota-Cone® can be inspected from the single loading hatch.

Liquids can be added through the optional spray line and a pin agitator can be added to facilitate liquid dispersion, granulation or de-agglomeration. Loading can accomplish with our automated drum loading and discharging system. Controls including variable frequency drive and PLC can be supplied in NEMA-4X or NEMA-7&9 explosion-proof design. Available sizes range from 0.1 to 500 cubic feet working capacity.

www.pauloabbe.com

Solvent Drying

The model TURBO-DRYER being exhibited at the 2020 Powder Show duplicates the actions of a full scale production dryer.

The material being dried is stationary on the rotating trays for a full revolution on each shelf. The material only moves when it is transferred through the slots to the shelf below.

Material is handled very gently with a minimum of particle breakage and fines formation. Therefore dust carryover Is very low, generally less than 1% of the throughput.

The dryer handles both water and solvent wet materials and removes solvents down to ppm levels without the need for vacuum.

Recent installations include drying: Lithium Carbonate, solvent wet Brominated fire retardant, animal feed supplement, carbon fiber and silver powder.

www.wyssmont.com

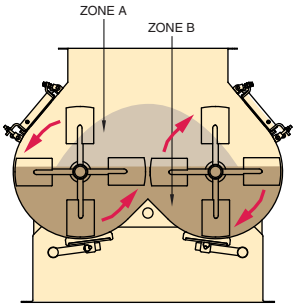
Fast, homogenous mixing

The Bella XN fluidized zone mixer from Dynamic Air is a twin-shaft design that uses a "weightless" central fluidized area to provide thorough yet gentle mixing of dry products

The twin-shaft Bella mixer

The Bella fluidized-zone twin-shaft paddle mixer by **Dynamic Air** achieves fast, high-capacity, low-shear, precision mixing of either dry bulk solids or liquids with solids. Regardless of particle size, shape or density, materials are mixed with a fast, efficient, and gentle action, with typical mixing times of 15–30 s. A weightless zone created by low-speed counter-rotating paddles generates low friction without shear. This makes it ideal for abrasive products and fragile products that cannot tolerate rough handling. Even flakes or spray-dried bodies remain intact.

The Bella mixer consists of twin drums which have two counter-rotating agitators with specifically angled paddles. The paddles sweep the entire bottom of both mixer drums and yet allow the mixer to be started under full load (Figure 1). The material in the mixer moves in a horizontal counter-clockwise direction at the perimeter



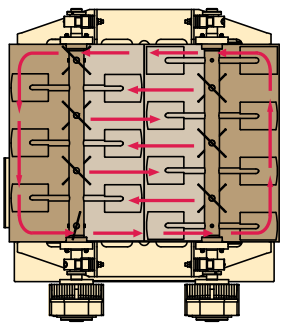


Figure 1 (right, top): In Zone A, fluidization promotes thorough mixing. Figure 2 (right): Material interchange between the two drums

while simultaneously moving both left and right in the center (Figure 2). The material in Zone B (Figure 1) is in its normal gravimetric state as it is being moved and dispersed. In Zone A, a weightless zone is created which effectively lifts the ingredients to an almost weightless state, allowing them to move freely and randomly, regardless of particle size and density. Thus the two zones' interaction becomes highly efficient as every particle moves rapidly to create a highly homogeneous mix, the key to the Bella mixer mixing technology for fast, precise mixing.

The Bella mixer is available in stainless steel and mild steel construction.

www.dynamicair.com/products/mixers.html

Freeze Drying System Technology:

Best level of process-control and reproducibility for rapid, safe freeze drying of your high-quality product

With over 70 years of experience, **Martin Christ** is the leading producer of, not only routine-process freeze dryers, but also of a series of product-specific, highly specialized lyophilizers from pilot to commercial production with far ending potential. Our freeze drying systems are used all over the world for all advanced applications. One of our key area of activity are pharmaceutical applications

Customized Solutions Designed & Made in Germany for commercial use

The construction of customized systems for sterile production of pharmaceutical products can always be considered a top level core competence of Martin Christ.

In this sector too, our name stands for utmost customer satisfaction all over the world. We develop and manufacture to the highest pharmaceutical standards to provide the best benefits for our customers.

Due to the high value of these active pharmaceutical substances, the requirements on the reliability and the technical implementation are extremely stringent. Highly potent drugs require specific solutions to prevent discharge, towards both the operator and the environment. Aseptic production over the entire process chain demands fully automatic loading and unloading, possibly in isolators, as well as a sterilisable freeze dryer design.

LyoShuttle our very innovative new system for automatic loading and unloading system offers a variety of advantages compared to current industrial standards from robust in operation due to small number of moving parts up to simple cleaning and disinfection of the complete LyoShuttle system. It is very much designed for integration in isolator environment.

www.martinchrist.de

Liquid-Solids Kneading at high solids content – EKATO vertical process blender VPT

EKATO SYSTEMS GmbH offers "made in Germany" technology for mixing pasty products with high solid contents.

EKATO SYSTEMS vertical process blender VPT

Quick and effective blending of such products requires agitation systems with high torque. Both Z-kneaders and horizontal ribbon blenders are quite expensive and difficult to discharge completely.

The **EKATO SYSTEMS** VPT vertical process blender offers 25% less torque demand and a discharge of up to 98%, compared with horizontal drum blenders.

The VPT features a heavy-duty "top entry" agitator, combined with a baffle system designed for liquid and solids blending to reduce both operation costs and batch times. The high impeller efficiency reduces energy input into the blend and avoids an excessive temperature rise during the batch cycle.

Benefits:
- vertical system with lower investment and maintenance costs compared to horizontal systems;
- no product wetted seals mean longer life;
- GMP-compliant design available;
- fast liquid incorporation in bulk solids – 30% less batch time;
- high-yield discharge system for maximum yield of valuable product – up to 98%;
- commercially proven design;
- worldwide sales and service network.

Applications:
- PVC in methylene chloride paste;
- aluminum/water paste;
- pigments in petroleum paste;
- graphite plus water/oil paste;
- cocoa powder/palm oil paste.

www.ekato.com

Sewage Sludge Drying

With Thin Film Dryer up to 95% DS

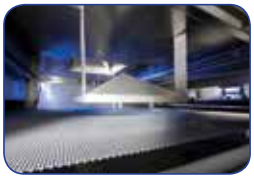
Thin Film Dryers have proven themselves in municipal and industrial sewage sludge drying since 1985 world wide. In Germany 42.162 tons dry matter from municipal sewage sludge were processed by Thin Film Dryers in 2017. By end of 2020 this number will have increased significantly. Two big new facilities will be started up then.

The technology ascertains safe and reliable operation. Spreading the sludge in a thin film on the heating wall by wiping blades offers a small product hold up of approx. 10 kg sludge per m². It enables to generate every concentration of dry substance up to 95%. Even the sticky phase, which occurs at sewage sludge between 45-60% DS, causes no problem, either in constant operation or after unexpected stops. Emptying is not needed and re-starting can be done without additional precautions. Thin Film Dryers accept all typical inlet sludge types. Indirect heating provides perfect conditions for vapour condensation and excellent conditions for direct connection to an incinerator. Thin Film Drying systems do not need ancillary equipment for feed product preparation or for dry material shaping. Maintenance is simple and does not require specialists.

www.sms-vt.com

IPCO: Highly efficient solidification solution for hot melts

in form of its flagship Rotoform system



The Rotoform process delivers consistently sized, hemispherical pastilles. As this is a completely dry system based on indirect cooling, there are none of the problems associated with underwater granulation, and the product leaves the system in a cold, solidified (i.e. non-sticky) state, ensuring clean, trouble-free packaging.

Key benefits of Rotoform solidification include:
- Size reduction in liquid phase.
- Free flowing end product.
- High quality pastilles, adjustable from 2–30 mm.
- No drying necessary as no contact between product and coolant.
- Low maintenance requirements.
- Regular appearance, defined weight and volume.
- High bulk density and good packaging properties.
- Dust-free production and product.
- Very low vapor/gas emissions.
- Low energy consumption.

Systems vary depending upon customer requirements, but a typical Hot Melt Adhesives processing system consists of remelting equipment for wax, a pair of mixing reactors, the Rotoform drop depositor (or strip former and cutter), steel belt cooler and downstream bagging and weighing equipment.

Typically, resin, premelted wax and polymer are blended in a mixing reactor on the level above the solidification plant. While one batch is prepared, the batch that has already been mixed is transferred to the Rotoform unit, a process that enables continuous pastillation.

The upstream part ensures that all ingredients of the hot melt are melted and mixed at the required temperature.

IPCO offers complete hot melt processing plants covering everything from initial system design, through solidification, to granule packaging solutions. Plants offer a high degree of flexibility, allowing quick and easy switchover between different types of hot melts.

www.ipco.com

Bulk Bag & Solids Processing

Premier Manufacturer of Custom Material Handling Equipment

Material Transfer is an industry leader in the custom design and manufacture of material handling equipment and systems for dry powders and bulk solids. A unique combination of application focused engineering, award winning designs and exclusive features results in equipment that offers class leading quality, value, durability, ease of use, and performance.

Equipment is fully assembled, inspected, and factory tested prior to shipment to ensure reliable performance, and customer satisfaction.

Material Transfer's application experience includes pharmaceutical, food, chemical, electronics, aggregate, agriculture, foundry, manufacturing, mining, packaging, pet food, petroleum, plastics, plating, stamping, governmental, explosives and automotive. Material Transfer's experience in dust tight handling of hazardous material in hazardous location environments with explosion proof or intrinsically safe equipment has placed them in the forefront of designing and building custom material handling equipment for these applications.

Over 95% of the equipment Material Transfer manufactures is custom designed for a customer's particular application requirements. Material Transfer has a team of talented engineers and the latest 3D computer software for equipment design, professional metal fabricators and machinists with the latest fabrication and CNC machining technologies, and an experienced team of machine assemblers to build its products.

Material Transfer's product line includes:

- Material Master Bulk Bag Conditioners - Quickly and safely return hardened materials to a free-flowing state.
- Material Master Bulk Bag Dischargers - Feature patented technology for clean, dust-tight discharge of your materials.
- Material Master Bulk Bag Fillers – From economical 4-post units to fully automated, high-output filling systems.
- Container & Drum Dischargers – Discharge any size container at heights to 40', dust-tight Lift & Seal System or open discharge. Patented Control-Link Rotation System for 180° rotation.
- Integrated Systems – To meet your application requirements.

www.materialtransfer.com

Jenike & Johanson Engineering Services

Jenike & Johanson, Inc. is the world's leading technology company for bulk material handling, processing, and storage. They deliver engineered solutions to achieve reliable powder and bulk solids flow based on proven theories and decades of project experience. With their skilled, highly technical team of experts and industry-leading innovations, they have successfully delivered bulk material engineering solutions for more than 55 years.

Bulk materials and their flow properties are at the core of all Jenike & Johanson's work. Every project (7,500+ to date) is truly unique. Clients are offered maximum flexibility in selecting services required to meet their bulk material handling needs. Jenike & Johanson does not follow the "one size fits all" concept – which can be a dangerous pitfall in engineering. Decisions made during the feasibility and engineering stages of a project are critically important for its success. If bulk solids systems are not engineered from the outset to handle the unique characteristics of the materials, process start-up time can be significantly delayed and design capacity may never be reached.

The engineers at Jenike & Johanson are renowned experts in the field of bulk material engineering. They are frequent keynote speakers at major industry events, routinely deliver informative webinars and customized courses, and publish thoughtful technical articles in top industry journals and publications – all this in order to provide clients with the latest insight on cutting-edge methodologies which make the powder and bulk solids handling aspect of the business run seamlessly.

The chemicals industry provides the building blocks for companies manufacturing paints, pigments, coatings, adhesives, resins, consumer products, and foods. 75% of all chemicals are handled in bulk solid form during manufacturing. When feeding powders to reactors or conveying wet cake from a centrifuge to a dryer, poor material flow can result in throughput limitations, non-uniform product, or dust emissions/spillage.

www.jenike.com

Ultra-high speed powder dispersion made simple

Ross SLIM Technology employs high shear for rapid and complete mixing of powders into liquids, avoiding agglomerates and dust formation

The **Ross** Solids/Liquid Injection Manifold (SLIM) is a technology for dispersing challenging powders like fumed silica, gums, thickeners and pigments using a specially modified high shear rotor/stator generator.

In both batch and inline designs, the SLIM is easy to retrofit into almost any process. In an inline set-up, the SLIM mixer pumps liquid from the recirculation tank while simultaneously drawing powders from a hopper. As the liquid stream enters the rotor/stator assembly, it immediately encounters the powder injection at the high shear zone. The mixture is then expelled through the stator at high velocity and recirculated back into the tank. In just a few short turnovers, solids are completely dissolved or reduced to the desired particle size.

This method for high-speed powder injection is ideal for dispersing small concentrations of hard-to-wet solids like CMC or xanthan gum (>5%). It is equally effective for solid loadings as high as 70%, as in the case of titanium dioxide or magnesium hydroxide slurries. By introducing solids sub-surface where they are instantly subjected to vigorous agitation, issues like floating powders, excessive dusting and formation of stubborn agglomerates ("fish eyes") are eliminated. Because the SLIM generates its own vacuum for powder induction and does not rely on external eductors or pumps, it is free of clogging and simple to operate.

Several models are available including automated skid packages where the SLIM mixer is piped to a jacketed tank and supplied with flowmeters, load cells, solenoid valves, level sensors and thermocouples all integrated into a PLC Recipe Control Panel. Each ingredient addition and process step can be pre-programmed so that mixer speed, mixing time, temperature, composition and batch weight are accurately replicated in every run.

Ross Inline SLIM powder induction mixer with built-in control panel mounted on a portable cart with work bench

Established in 1842, Ross is one of the world's oldest and largest manufacturers of process equipment, specializing in mixing, blending, drying and dispersion. **www.highshearmixers.com**

Measuring PVC Level In Silos

Measurement Objectives:

- ✓ Reliable production supply thanks to continuous inventory level monitoring
- ✓ Reliable long range measurement even with extremely low tank levels in narrow silos
- ✓ No need for instrument flushing systems despite presence of products that are extremely sticky and dusty

Background:

A company that manufactures and processes PVC stores a variety of product shapes in several slim silos reaching heights of more than 65 feet (20 m). They supply the product for their own production as well as to third-party producers. In addition to PVC powder and PVC granulate some regenerated PVC that is extracted from old shredded products is also stored.

The level in the silos must be continuously measured to ensure a reliable production supply. The atmosphere in the silos is extremely dusty and the PVC dust is very sticky. The customer was interested in a type of non-contact radar measurement that did not require any kind of antenna cleaning since there is no compressed air supply.

A KROHNE OPTIWAVE 6500C 80 GHz FMCW radar level measurement instrument with a 3 inch (80mm) lens antenna specifically designed for solid applications is ideal for use in these applications.

FMCW stands for "Frequency Modulated Continuous Wave" and is one of two popular radar level measurement techniques. When compared to the pulse method, FMCW features a much wider dynamic range and better signal strength. Those advantages clearly benefit these types of challenging solids and powder applications as well as many difficult process liquid level and reactor vessel applications.

The unique lens antenna is especially beneficial in powder applications since it is self cleaning, and it focuses the available signal much more than a horn can which also improves performance in tall, narrow vessels.

This solution allows the company to monitor the level in the silos at any time. It also eliminates any chance of running on empty which would put the production processes at risk.

KROHNE has several process level solutions for all types of solids or liquid applications including FMCW radar, ultrasonic and mechanical technologies. If you have a challenge with level, please contact us to evaluate it and suggest some possible solution.

http://us.krohne.com

Flameless Venting

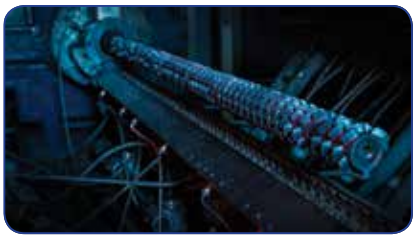
CV Technology is proud to announce that the Interceptor-QR is the first flameless venting system to have completed a FM Approval to the new Approval Standard 7730. The 7730 standard is the most recent and most rigorous testing methodology to have been developed. Using the methodology stresses the devices under more realistic conditions than had been developed by previous standards. CV Technology continues to be a pioneer in the combustible dust protection industry with the most complete certification for flameless venting technology in the world.

The dust and flame retention capability of the Interceptor-QR make it ideal for indoor explosion venting applications. With a simple installation, easy refurbishment, and process friendliness, the Interceptor-QR is a superior explosion mitigation technology. Interceptor-QR flameless vents can be used on a variety of process equipment. These vents are designed to be used on equipment located indoors since they eliminate the release of a flame ball. Flameless vents are ideal for pneumatic conveying equipment, dust collectors, bins, cyclones, bucket elevator, mills, silos and dryers.

For more information about CV Technology or flameless vents, please call 561-694-9588 or visit

www.cvtechnology.com

B&P Littleford's Innovative Compounding Technology



For more than a century, **B&P Littleford**'s industrial equipment has been helping customers make their manufacturing processes better, more efficient, and more profitable. B&P designs and builds a wide spectrum of mixing, drying, extruding, compounding, and centrifugal separation equipment for large- or small-scale manufacturing applications.

Their exclusive TriVolution Compounder (3 strokes per screw revolution) offers a dramatic shift in process performance while using less energy than competitive products. The design basis enables an easy transition for new owners as the unit retains the basic modularity of most familiar compounding extruders. This machine – like all of the B&P Littleford compounding equipment – is designed and built in Saginaw, MI. Full-service testing, parts, and rental equipment are readily available for the full line of products, as well.

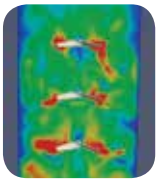
Whether it is planning a new product, seeking to enhance production of a current product line, modifying a formula, trying to boost environmental performance, or simply need increased efficiency in production, B&P Littleford will customize an industrial machine solution to fit their customers' needs.

www.bplittleford.com

Advanced Solutions For Optimized Process Performance

For over 90 years, **SPX FLOW**'s Lightnin brand has been recognized as the leader in offering mixing solutions, providing a complete package of products and services for the specialty chemical, pharmaceutical, biotechnology, minerals processing, petroleum and waste water treatment markets. Whether top enty, side entry, bottom entry, portable clamp mount, mechanically sealed or magnetically driven, Lightnin builds mixers for all of your needs. With a full range of in house modeling capabilities (CFD, FEA, experimental mixing testing), Lightnin has a dedicated R&D group, providing process consulting services for all aspects of your mixing processes.

SPX FLOW Lightnin consulting services begins with a careful evaluation of a client's mixing process need, which might cover a new application or improving an existing application's performance. Understanding the desired process result and how the mixer design and vessel design effects it essential for success. The Lightnin application engineering and R&D teams will benchmark the current process needs, vessel design including internals, feed and outlet locations for continuously operations to best gauge the mixing design requirements.



For existing systems, the mixer performance will also be benchmarked, focusing on the client's pain points regarding the existing mixing process. Once these baselines are established, Lightnin's research and development and application engineering teams design the optimal mixing solution utilizing both experimental and computational techniques within Lightnin's Process Technology Mixing Laboratory in Rochester, NY.

After a detailed process assessment, Lightnin can then design a new mixing solution for new processes and a retrofit mixing solution for processes with existing mixers installed. Lightnin's Research and Development team uses proven scale up techniques to translate small scale results into full scale mixer designs. For complex reactors, Lightnin's Mechanical Engineers can predict the mechanical forces that the mixing solution will impart on the vessel and vessel internals, which can include Finite Element Analysis (FEA) of the mixer and mixer / vessel interaction. In addition, the installation and maintenance requirements for the mixing solution are included with the recommendation, which provides our clients with peace of mind that the solution will provide both process results and long term reliability.

SPX FLOW Lightnin enjoys a global reputation for durable, long lasting mixers, agitators and surface aerators for fluid processing systems in a wide range of markets, including state of the art impeller technology for diverse applications. Lightnin offers a worldwide service network, mixer repair, gearbox repair and exchange and replacement parts programs. Lightnin also offers mixing seminars for your engineering staffs as well as lab testing solutions in both Europe and Asia. Look to Lightnin for knowledge, technology and service excellence.

www.spxflow.com

Economic Indicators

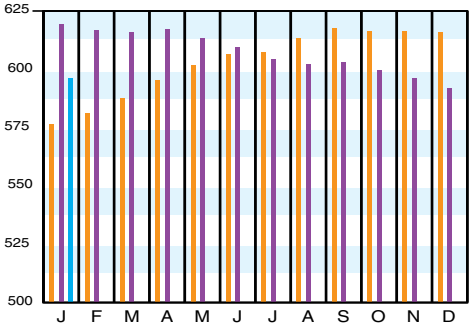
2018 2019 2020

Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	Jan. '20 Prelim.	Dec. '19 Final	Jan. '19 Final
CE Index	596.2	592.1	618.7
Equipment	724.1	716.9	756.9
Heat exchangers & tanks	618.7	611.0	676.5
Process machinery	721.7	714.5	732.2
Pipe, valves & fittings	957.3	951.1	978.9
Process instruments	419.1	419.0	416.0
Pumps & compressors	1080.2	1075.8	1060.6
Electrical equipment	563.8	561.9	554.7
Structural supports & misc.	767.1	750.2	841.1
Construction labor	333.8	338.5	333.9
Buildings	588.3	585.7	601.6
Engineering & supervision	313.7	312.7	316.9

Annual Index:
2012 = 584.6
2013 = 567.3
2014 = 576.1
2015 = 556.8
2016 = 541.7
2017 = 567.5
2018 = 603.1
2019 = 607.5

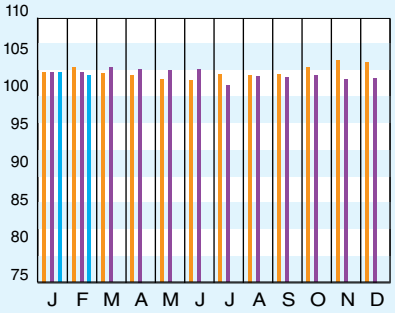


Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76–77.)

CURRENT BUSINESS INDICATORS

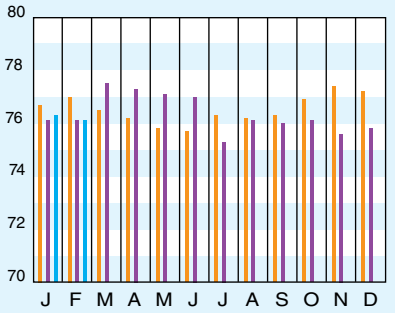
	LATEST	PREVIOUS	YEAR AGO
CPI output index (2012 = 100)	Feb. '20 = 102.4	Jan. '20 = 103.1	Dec. '19 = 102.2	Feb. '19 = 103.1
CPI value of output, $ billions	Jan. '20 = 1,996.6	Dec. '19 = 2,022.0	Nov. '19 = 1,987.5	Jan. '19 = 1,938.3
CPI operating rate, %	Feb. '20 = 76.1	Jan. '20 = 76.6	Dec. '19 = 76.0	Feb. '19 = 77.4
Producer prices, industrial chemicals (1982 = 100)	Feb. '20 = 241.9	Jan. '20 = 245.8	Dec. '19 = 242.9	Feb. '19 = 257.4
Industrial Production in Manufacturing (2012 =100)*	Feb. '20 = 104.9	Jan. '20 = 104.8	Dec. '19 = 105.0	Feb. '19 = 105.3
Hourly earnings index, chemical & allied products (1992 = 100)	Feb. '20 = 186.1	Jan. '20 = 188.2	Dec. '19 = 187.9	Feb. '19 = 185.3
Productivity index, chemicals & allied products (1992 = 100)	Feb. '20 = 99.2	Jan. '20 = 99.2	Dec. '19 = 98.1	Feb. '19 = 97.1

CPI OUTPUT INDEX (2000 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)

CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2000 to 2012
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the *CE* Plant Cost Index (CEPCI; top) for January 2020 (the most recent available) increased from the previous month's value, reversing a general downward trend that has continued for most of 2019. Of the four major subindices comprising the overall CEPCI, the Equipment, Buildings, and Engineering & Supervision subindices increased in January, while the Construction Labor subindex saw a small decrease. The current CEPCI value is 3.6% lower than the corresponding value from a year ago at the same time.

The annual average CEPCI value for 2019 was calculated to be 607.5, which is higher than the yearly average value for 2018 despite the generally decreasing trend in the monthly values.